# IMPACT OF TREATED MUNICIPAL WASTEWATER ON HEAVY M~~A~~ETALS ACCUMULATION,GROWTH AND DEVELOPMENT OF TURNIP

**THESIS**

SUBMITTED FOR THE AWARD OF THE DEGREE OF

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BY


**TABASSUM PARVEEN**

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ALIGARH (INDIA)


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"Dedicated

To My Beloved Parents

Who Gave Me Strength to

Come

Up To This Level."

## CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **"Impact of treated municipal wastewater on heavy metals accumulation, growth and development of turnip"** in partial fulfillment of the requirements for the award of the degree of **Doctor of Philosophy** in **Botany** and submitted in the **Department of Botany, Aligarh Muslim University, Aligarh** is an authentic record of my own work carried out during a period from December 2005 to October 2009 under the supervision of **Dr. Arif Inam**, Professor, Department of Botany, Aligarh Muslim University, Aligarh, and **Dr. Indu Mehrotra**, Professor, Department of Civil Engineering, Indian Institute of Technology Roorkee, Roorkee.

The matter presented in this thesis has not been submitted for the award of any other degree at this or any other University/ Institute.

**(Tabassum Parveen)**

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This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

**(ARIF INAM)**
(Supervisor of research)
Professor, Department of Botany
Aligarh Muslim University
Aligarh-202002, INDIA

**(INDU MEHROTRA)**
(Co supervisor of research)
Professor, Department of Civil Engg.
Indian Institute of Technology Roorkee,
Roorkee-247667, INDIA

**Dated:** October 24 , 2009

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# CHAPTER 1
# INTRODUCTION

India supports more than 16% of the world's population with only 4% of the world's fresh water resources (Rattan et al, 2005). The agriculture sector in the country has been major user of water while the share of water allocated to irrigation is likely to be decreased by 10-15% in the next few years. Some of the steps which must be taken up immediately to overcome this deficit are conservation, optimum utilization of fresh water and recycling of wastewater as fresh water resources are adversely affected day by day due to increase in population, industrialization, urbanization, and recurring droughts. In India population has grown far above the normal expectations and so has the amount of water needed to produce food and vegetables and to fill the number of the other needs we have for water. The greatest single use of fresh water in here and else where also, is the irrigation which accounts more than 60-70% of the total water consumption. It may be of interest to note that Asia with approximately 31% of its cultivated land under irrigation has surprisingly the maximum irrigation land. The problem arises further in such areas as efficiency of irrigation water use is rather low because of high evaporation, seepage loses and poor drainage systems therefore, in some cases about 40-80% of the water withdrawn for irrigation not reaches to the required destination. The conditions explained above hence forces the farmer to shift towards the waste waters in what ever form it is available to them at the time of their need.

Therefore, the use of sewage in farming seems to have gained the acceptance among farmers of today, although sewage farming is not new as during the middle of the last century, attention was drawn to the fertilizing value of sewage and even recommended for land treatment as the best method of its disposal. Findings of the British authorities considerably helped in the development of sewage farming in England and its irrigation spread very rapidly throughout the Europe. In India also sewage irrigation has been the predominant mode of its disposal ever since sewerage system came to be introduced and large numbers of sewage farms were disposing of sewage satisfactorily in different states of the country (Mahida, 1981).

According to a report published by the Central Pollution Control Board of India (CPCB), 423 class I cities with more than 1,00,000 and 498 class II towns with population between 50,000 to 1,00,000 of the country in which more than 70% of urban population houses, generate about 26,254 million liters per day (ML/d) sewage and the wastewater generated from the major industries has been reported to be approximately 83,048 ML/d (Bhardwaj, 2005). Therefore the farm scientists in India are, suggesting the use of wastewater wherever it is available for irrigation and the farmers are willing to opt for its greater consumption in regions of fresh water scarcity near the urban areas specially for vegetable cultivation. The use of sewage waste water for irrigating the agricultural lands is therefore, on the rise and treated sewage is comparatively a better source of water to minimize the problems of its disposal, and to overcome the lack of fresh water availability to farmers. In addition the nutrients present in it provide fertilizer benefits to crops thereby decreasing the burden on farmers and environment. It may be pointed out that domestic sewage mainly consist of discharges of dirty water from houses. It is complex mixture of mineral and organic matter in various forms including particles of different size in solution, suspension and colloidal dispersion. It also contains living matter, specially bacteria, viruses and protozoa. Most of the bacteria are relatively harmless but some of them are dangerous being pathogenic. Therefore, the farmers as well as the consumers are to be alarmed about them. Another negative aspect of this water may be, in certain instances, nutrients are in excess of plant needs and may cause problems related to excessive vegetative growth, delayed maturity and poor quality in addition to presence of heavy metals and salts.

Vegetables are regarded as an essential constituent of food, because of their richness of carbohydrates, proteins, fats, minerals and vitamins. In India vegetable consumption is many times more than the European countries due to two main reasons, first, the vegetarian food habit of a very large population because of their religious faith and secondly, the lower cost of the common vegetables compared with meat, fish, eggs and milk products. It is also important that compared to other crops many vegetables can be grown throughout the year and can be marketed regularly, because some of them are ready within a short span of two to three months only and can be raised profitably specially the underground vegetables like turnip, radish, potato etc. Among root crops turnip has been used as a vegetable for human consumption in Europe since prehistoric times as it is rich in vitamin C, dietary fiber, and it has antioxidants low calories. It lowers the risk of high blood pressure and diabetes, cancer of the stomach, pancreas, bladder and lung. It is also a good source of calcium, phosphorus and magnesium. Turnip greens are excellent source of riboflavin, and iron. It contains Water (119.4 g), Protein (1.17 g), Carbohydrates (8.36 g), Fiber (2.3 g), Sugars (4.94,) Total fat (0.13 g), Saturated fat (0.014 g), mono unsaturated fat (0.008), Polyunsaturated fat (0.069), Cholesterol (0 mg) and calories equivalent to 36 g in 130 gm of turnip or one cup of turnip cubes (Anonymous, 2008). The best quality turnips are successfully grown in the Northern plains and hilly terrains of India including Uttarakhand where the city of Roorkee is situated. It grows best in a moderately deep loam, fertile and slightly acid soil and does not do well in soils that are of high clay texture, wet or poorly drained as for good root growth turnip needs a loose and well aerated soil.

Most plants require seventeen essential elements including Ni which was added more recently (Hopkins, 1995) among the list of essential elements for their normal growth and development. Of these N, P, and K are the three major macronutrients effective in promoting the crop yields and required in larger quantity. These nutrients are commonly present in sewage wastewater along with some other nutrients like Ca, Mg, S and micronutrients like Cu, Zn, Mn and Fe although these micronutrients are also categorized as heavy metals and may be toxic to plants and disturb a wide range of biochemical and physiological processes, such as photosynthesis, pigment synthesis, protein metabolism and membrane integrity if taken up at excessive levels (Yang *et al*, 2008). Similarly there may be some heavy metals like Cd and Cr which have not shown any specific functions in plant growth and the former element is toxic to all organisms. Its excessive presence in soil may cause many toxic symptoms in plants, such as reduced growth, especially root growth, disturbances in mineral nutrition and carbohydrate metabolism and may therefore, strongly reduce the biomass production . While Cr toxicity appear as wilting of tops and root injury, and chlorosis in young leaves (Pendias and Pendias, 1992).

Keeping these points in view, and due to the presence of nutrients mentioned above studies have been undertaken to investigate the effect of anaerobically treated sewage wastewater based on four pot experiments with the following aims:

1. To study the physicochemical properties including presence of various essential nutrients, heavy metals and coli forms of sewage wastewater of the two sewage treatment plants.
2. To study the comparative effect of different concentrations of 38 ML/d wastewater and tap water for getting suitable concentration and obtaining the optimum dose of phosphatic fertilizer on the basis of growth performance and heavy metal accumulation in root and leaf (Experiment-I) of turnip.
3. To study the comparative effect of different concentration of 38 ML/d wastewater and tap water with different doses of potassic fertilizer to obtain the suitable concentration and optimum dose of potassic fertilizer on the basis of growth performance of turnip and heavy metal accumulation in root and leaf (Experiment-II).
4. To study the 34 ML/d wastewater under two concentrations and different doses of phosphatic fertilizer and to obtain suitable concentration of wastewater and optimum dose of phosphorus on the basis of growth performance and heavy metal accumulation in root and leaf of turnip (Experiment-III).
5. To study the 34 ML/d wastewater under two concentrations and different doses of potassic fertilizer and to obtain suitable concentration of wastewater and optimum dose of potassium on the basis of growth performance and heavy metal accumulation in root and leaf of turnip (Experiment-IV).
6. To observe if the crop may be suggested as a suitable vegetable for the cultivation under two different wastewaters one generated from 38ML/d located at Saharanpur and another 34ML/d located at Noida on the river Hindon which runs for a short distance between the Ganga and Yamuna and merges in Yamuna, the two major rivers of North India.

# CHAPTER 2

# LITERATURE REVIEW

Cropping with sewage water is a practice that has been around for the last few centuries as efficient nutrient recycling system. Wastewater reuse, although becoming a necessity due to the limitation in the availability of fresh water for irrigation, has a health risk for grower as well as for consumer. The nutrients present in wastewater provide fertilizer benefits to crops. But in certain instances, nutrients are in excess of plant needs and cause problems related to excessive vegetative growth, delayed maturity and poor quality. Studies carried out by many farm scientists during nineties and onwards for the use of wastewater in vegetables were concerned mainly about the heavy metals contrary to earlier studies of sixties to eighties which were mainly concerned with use of NPK fertilizers and farm yard manure (FYM) and their role in growth and yield. It may be pointed out here that sufficient references were available on turnip when it was grown without waste water while references on turnip grown with waste water were comparatively few as may be observed in the following pages. In brief mention may be made of Thapar, (1960) who suggested that the requirement for nitrogen and phosphorus of turnip was more than potash. Later Reith and Inkson, (1963), in a detailed study of fertilizer and FYM application, reported that root yield showed small to moderately high response to nitrogen in most experiments. Phosphorus increased the root yield in most of the experiments while potassium recorded better response in only half of the experiments and its effect on yield was in general less than that obtained with nitrogen application. Similarly Del Velle and Harmon, (1970) studied the effect of different nitrogen levels and sources on turnip greens at Tifton (Georgia), USA. During their study nitrogen, increased the yield, leaf blade weight and nitrogen content and also improved the color. At IARI (New Delhi) Lal and De, (1972) worked out the fertilizer and moisture requirements of turnip. An increase in nitrogen fertilizer dose from 50-100 kg/ha increased its recovery in the plant and fresh root yield was also increased. Application of phosphorus (25 and 50 kg $P_2O_5$/ha) recorded an increase up to 2.1 t/ha while potassium (50-100 kg $K_2O$/ha) significantly reduced the root yield of turnip. Bradley *et al*, (1973) studied the response of turnip to nitrogen and plant spacing at Arkansas valley (USA). Application of 134.4 kg N/ha, half before sowing and half after emergence, increased turnip greens yield markedly. During same year Islam and Rashid, (1973), in Bangladesh, tested the tolerance of various vegetable crops to the spray of aqueous solution of urea of different concentrations, and turnip was more tolerant to nitrogen than radish. Working on sulphur coated urea Sharma *et al,* (1976), studied at Albana (USA) the effect on yield, nitrogen uptake and nitrate content in turnip greens and other vegetables and reported that the type of soil gave differences in response of turnip greens. Shimada *et al,* (1977) compared the effect of ammonium chloride, ammonium sulphate and urea applied as fertilizer to radish, turnip, and carrot in a wet and dry year at Matsudo (Japan). The yield with ammonium chloride was better than those obtained with other two conventional fertilizers. Gill, (1979) while working at Katrain in the kullu valley (H.P.) on Pusa Swarnima turnip, recommended the application of 200 kg/ha of diammonium phosphate and 100 kg/ha of muriate of potash at the time of sowing together with 40-50 tonnes/ha of FYM.

30 years back

More recently Sirohi, (1980) compared the performance of several varieties of turnip, including snow ball, at IARI, New Delhi while Bagchi, (1982) studied the effect of nitrogen nutrition on radish, turnip, beet root and fodder variety of pearl millet at Calcutta (W.B.). In continuation Rajput and Singh, (1982) in a 2 year trial conducted at Varanasi (U.P.) where highest doses of NPK (100-80-80) gave the maximum productivity while Smirnov *et al,* during the same year studied the effect of nitrogenous fertilizer application in 18 vegetable and fodder root crops at Moscow (USSR). They noted that nitrate accumulation was highest in Brassica crops in general and turnip in particular. Two pot and two field experiments were conducted by Vieira *et al,* (1998) to study the effect of N fertilization on nitrate accumulation, yield, and leaf quality of turnip greens at Lisbon, Portugal. When N fertilizer dose was increased from 100 to 250gm$^{-3}$, plant fresh weight was increased up to 7.4 and 8.6% and nitrate concentration was increased by 279 and 1315% respectively, in growth room as well as outdoor pot experiments, showing that turnip greens may easily reach conditions of luxury consumption of N. A dynamic model on the effect of soil P and fertilizer P on crop growth, P uptake and soil P in arable cropping system was given by Greenwood *et al,* (2001) at Wallesbourne, UK, while considering five vegetables crops including turnip. A study on different irrigation strategies on turnip forage crop growth rates, dry matter yield, water use efficiency, changes in soil water, nutritive characteristics and mineral content was conducted on different soil types at different sites during two years by Jacobs *et al*, (2004). At site 1, response to irrigation was adverse by insect damage and delayed sowing, particularly in year 1. However, there were significant increases in dry matter yield to weekly irrigations in both years, with responses more in second year, and response in both years was higher where nitrogen was applied. The phenolic compounds and organic acids of turnip (*Brassica rapa* var. *rapa* L) edible parts (leaves and stems, flower buds and roots) were determined by Fernandes *et al*, (2007). The results revealed a profile composed of 14 phenolics. A screening of the antioxidative potential was also performed where turnip flower buds exhibited the strongest antioxidant capacity.

## 2.1 EFFECT OF WASTEWATER ON TURNIP (*Brassica rapa*)

Naheed *et al*, (1988) at Lahore (Pakistan) irrigated sugar beets, carrots, spinach, cauliflower, coriander, lettuce, turnip and radish with raw sewage after dilution in 1:1 ratios with ground water. They noted that raw sewage significantly affected the growth and the taste of the vegetables studied. The accumulation of heavy metals was in the order of Fe > Cu > Cr > Pb > Ni.

A study was conducted by Midrar-ul-Haq *et al*, (2005) in summer and winter seasons of the years 2000-2001 to observe the bioaccumulation of micro elements by bottle gourd, brinjal, coriander, hot pepper, maize, okra, spinach, spong gourd, radish, turnip and wheat grown on contaminated soils of NWFP, (Pakistan). The highest values of 75.0, 137.9, 982.0, 286.9, 8.3, 15.0, 73.0, 72.0 mg $kg^{-1}$ were obtained in effluents irrigated plants and 34.2, 18.6, 120.9, 34.0, 2.6, 4.2, 16.0 and 20.0 mg $kg^{-1}$ in tube well water fed plants for Zn, Cu, Fe, Mn, Cd, Cr, Ni, and Pb, respectively and also compared the toxic and excessive levels of heavy metals. The comparison showed that 90, 28, 43, 98 and 30% of samples contained toxic or excessive levels of Cu, Cd, Cr, Ni and Pb respectively. The concentrations of these elements in effluent irrigated plants were higher than those in ground water irrigated plants and also higher than those generally reported by other workers.

Jacobs and Ward, (2006) studied the effect of dairy effluent on soil nutrient status, dry matter yield, nutritive characteristics and mineral contents of turnips. They applied 0, 16, 23 and 33 mm/ha levels of effluent. Analysis of the effluent indicated high levels of potassium and sodium and moderate level of nitrogen. Effluent applied at the rate of 23 and 33 mm/ha resulted in higher leaf, root and total dry matter yields than where the effluent was not given. Crude protein concentration in leaf and root was also increased by effluent application. Contrary to it magnesium content of turnip leaves was decreased with higher effluent application rates, while potassium and sulphur contents of roots were increased. They concluded that there is potential to use dairy effluent to increase forage crop dry matter yield during summer season in dry land areas of southern Australia. During the same year turnip dry matter (DM) yield was also surveyed for 266 turnip crops on 142 dairy farms in south western Victoria by Jacobs *et al*, (2006) although in this study waste water was not applied. The average DM yield was 5 t/ha, although the range was from 0.4-19.2 t DM/ha. Factors that had the greatest effect on total DM yield were secondary cultivation practices, total water received by the crop, gravimetric soil moisture and temperature at sowing, seeding density and insect damage.

In another study on turnip without waste water was conducted by Zheng *et al*, (2007) who investigated heavy metal contamination in 20 vegetables including turnip cultivated popularly around Huludao zinc plant and collected soil samples from eight sampling plots to investigate health risk of Hg, Pb, Cd, Zn, and Cu to the inhabitants around the plant in China via consumption of vegetables. Transfer factor (TF) values of Hg, Pb, Cd, Zn, and Cu from soil to vegetable and the target hazard quotients (THQs) to the possible health risks to local population through the food chain transfer were calculated. TF values of heavy metals from soil to vegetable decreased in the order of Cd>Zn>Cu>Pb>Hg. These TF values of leaves were higher than other tissues. Similarly some more references on turnip like Rodriguez-sevilla *et al*, (1999), Gong *et al*, (2001), Moreira *et al*, (2005), and Nishijima *et al*, (2005) were noted but these were also not related to our problem.

Arora *et al*, (2008) assessed the levels of different heavy metals like iron, manganese, copper and zinc in vegetables irrigated with wastewater at Ganganagar (India). The range of various metals in wastewater irrigated plants was 116-378, 12-69, 5.2-16.8 and 22-46 mg/kg for Fe, Mn, Co and Zn, respectively. The highest mean levels of Fe and Mn were observed in mint and spinach, whereas the levels of Cu and Zn were maximum in carrot. Heavy metal concentration was in the order of Fe >Mn >Zn >Cu for all the plants grown by them except radish, turnip and carrot where the trend was Fe >Zn >Mn >Cu. The present study highlighted that both adults and children consuming vegetables grown under wastewater-irrigation ingest significant amount of these heavy metals.

## 2.2 EFFECT OF WASTEWATER ON VEGETABLES

Ajmal and Khan, (1983) at Aligarh studied the effect of different concentrations (100, 75, 50 and 25%) of sugar factory effluent of Aligarh and Bulandshahr on soil as well as on kidney bean and pearl millet and observed that germination was 100% in the water-irrigated soil, while it was between 99% and 91% under different concentrations of effluents. The ground water and 25% effluent irrigated soils were more suitable for germination. Therefore, they suggested the use of effluent for irrigation after suitable dilution. Ajmal and Khan, (1984a) further studied the effect of effluent from Mohan Meakin breweries Ltd., Ghaziabad (MMBL). Germination of wheat and pea was restricted to 80 and 90% respectively under 100% effluent but with 50 and 25% concentration, it was quick. Similarly, the growth was also restricted with 100% effluent while 50% proved beneficial. In continuation, during the same year, (1984b) they also applied four concentrations of vegetable ghee manufacturing unit effluent again taking pea in addition to mustard. Germination was delayed and restricted to 90% of normal when undiluted effluent was given, whereas it was normal under other concentrations. Undiluted effluent inhibited the growth whereas 75% effluent enhanced it. They were of the opinion that this concentration was suitable as it can supply some of the essential nutrients. Similarly, Ajmal *et al*, (1984), also applied Glaxo Laboratory India Ltd. effluent (GLLE) to kidney bean and pearl millet. The undiluted GLLE checked the germination in kidney bean to some extent while in pearl millet it was beneficial. It was also noted that 75% effluent in pearl millet and 25% in kidney bean enhanced the height of plant whereas 100% GLLE retarded it in both crops.

Ajmal and Khan, (1985a) further studied the effect of Modi textile factory effluent, Modinagar (U.P.) on kidney bean and lady's finger. They observed gradual increase in $Na^+$ content of plants with increase in effluent concentrations. In plants grown under 50% effluent, the concentration of $K^+$, $Ca^{2+}$, $Mg^{2+}$ was highest followed by 25%, 75% and 100%. Higher concentrations (100% and 75%) inhibited and delayed the germination but it was normal with lower concentrations. In another experiment (1985b), they applied 0.1, 0.2, 0.4, 0.6, 0.8, 1.0, 1.5, 2.0, 2.5, 3.0 and 4.0 dilutions of electroplating factory effluent to hyacinth beans and mustard. Germination was delayed with increase in concentrations and in mustard it was totally inhibited under 1.5% effluent. The metal content in the hyacinth plants increased with increasing concentration but after 1.0% effluent, the concentration of Ca, Mg, Na, K, Cu, Zn and Fe was decreased in plants except Cr which increased throughout, while Cd, Ni, Co, Mn and Pb were not detected in hyacinth bean plant. It may be pointed out that work undertaken by Ajmal and his associates at Department of Applied Chemistry of this University was based mainly on chemistry of soil and wastewater and its effect on some plants including the vegetables. However, their work was restricted to seed germination and up to seedling growth only and not in terms of crop growth and productivity.

Monem, (1988) studied the bacteriological examination of vegetables irrigated with wastewater at Dakahlia (Egypt). Post harvest tests on vegetables like radish, green onion, spinach, lettuce, pepper and tomato were taken up and irrigated with wastewater. It was noted that the highest bacterial count on leafy vegetables, spinach with 800,000 total coliform (TC) and 15,000 faecal coliform (FC) and lettuce with 1,30,000 TC and 7000 (FC) which was decreased after washing. This decrease varied according to the nature and structure of plant organ. Sahai and Srivastava, (1988a) studied the seed germination and seedling growth of cauliflower and cabbage using various concentrations ranging from 1, 2.5, 5, 10, 25, 50, 75 and 100% of fertilizer factory effluent. They observed a corresponding decrease in percentage of seed germination and speed of germination index with increase of concentration. In 75% and 100%, no germination took place while 2.5% wastewater proved best for seedling growth. They were of the opinion that high toxicity of the effluent may be due to the presence of urea nitrogen and ammonia-N in the effluent, therefore, recommended that 2.5% concentration of the wastewater may be used as liquid fertilizer. During the same year (1988b), they also studied the impact of fertilizer factory wastewater on french beans and noted an increase in chlorophyll a and chlorophyll b of seedlings up to 2.5% effluent only and decrease thereafter. The carotenoid content, however, increased gradually with increase in concentration.

Jabeen and Saxena, (1990) studied the effect of Sarya distillery and fertilizer factory effluents on pea at Gorakhpur. Growth was favourable when lower concentrations up to 5% of distillery and 2.5% of fertilizer factory were used which ultimately increased the dry matter, pigment and protein contents. They concluded that both wastewaters after proper dilution may be used for irrigation and may be an additional source of nutrients Truby and Raba, (1990) at Freiburg (Germany) noted uptake of Zn, Cd and Pb by Chinese cabbage, lettuce, fodder beets, spinach, cabbage, carrots, potatoes, radish, beet roots, celery, onions, bush beans, strawberries, cucumbers and tomatoes when irrigated with sewage wastewater. They noted low levels of heavy metals in fruit vegetables and strawberries. However, lettuce, fodder beets, spinach, celery and carrots grown in a neighboring uncontaminated field had high Cd contents. They concluded that uptake of heavy metals by vegetables could not be predicted by measuring them in the soil alone.

Inam and his associates have also undertaken some studies at Aligarh on wastewater quality and vegetable cultivation. Mention may be made of Aziz and Inam, (1995) where post irrigation effect of sewage water on some crop plants and agricultural soil was observed. The pH of sewage was almost neutral but the values for EC, total dissolved salts and cations were high compared to Indian standards. Soil irrigated with sewage showed no significant change in pH, EC, organic carbon and some cations. On the other hand the soil as well as the crops studied showed the accumulation of heavy metals in general and Pb, Cr and Ni in particular because of electroplating industrial waste of Aligarh city mixed with sewage. Among the crops, in general N and Ca content was more in leaves of all crops as compared to other plant parts and maximum in radish while minimum in cauliflower. P was more in leafy vegetables except cauliflower while grain of wheat and stem of mustard had more phosphorus. P, K contents were more in leaves of wheat and spinach as compared to stem while the reverse was true in the case of mustard, cucumber and radish. Except radish, all crops contained more Na in leaves as compared to any other part. Similarly using the same wastewater Khan *et al,* (2003) in a preliminary study on morphophysiology and yield of spinach and fenugreek concluded that sewage wastewater application enhanced chlorophyll a, b and total chlorophyll contents, photosynthetic rate, photosynthetic water use efficiency, growth and yield in both crops.

Salim *et al,* (1995) in Palestine studied the effect of root treatment of cauliflower, spinach, and parsley plants with Pb and Cd. They irrigated vegetables with sewage water contaminated with heavy metals and reported that both metal ions inhibited the growth, with plants treated with Cd showing more symptoms of toxicity than Pb. Cd was more in the edible parts of the three treated plants whereas, Pb was more in cauliflower and spinach. Metal ion concentration and total metal content of treated plants increased with increase of concentration of Cd or Pb. Guttormsen *et al,* (1995) carried out an experiment over a three year period with Chinese cabbage and carrots grown in a sandy soil with pH adjusted to 5.5 and 6.5. The NPK fertilizers containing 1, 30, 90 and 400 mg Cd $kg^{-1}$ P were applied at the rate of 0.07, 2.1, 6.3 and 28 g Cd $ha^{-1}$ $yr^{-1}$. The increased Cd application rates through NPK fertilizers increased the Cd concentration in both vegetables but the differences among treatments were not significant.

Eid and Shereif, (1996) working in Egypt ~~and~~ in irrigating barley, broad bean and rice by (I) raw wastewater (untreated), mixed with fresh water (1:2) for a final EC of 5 ms $cm^{-1}$ (II) raw wastewater, mixed with fresh water (1:6) for a final EC of 2 ms $cm^{-1}$ (III) treated wastewater mixed with fresh water (1:6). The dry matter yield was maximum from raw wastewater mixed with fresh water (1:6). The effect of irrigation was insignificant on Zn and Cu contents of plant. However, the contents of P, N, Mn and Ni increased significantly with mixed wastewater compared to fresh water. The contents of Fe and Mn in straw were more than grain or seed while the contents of N, P and K were significantly greater in grain or seed than in straw. Also in the year 1996 Shalaby *et al,* at Shebin el Kan performed a green house experiment and studied the effect of different types of waters namely, sewage wastewater, oil and soap company and superphosphate factory on mineral composition of anise, caraway, coriander, spearmint, geranium and sweet basil. The plants were irrigated by three dilutions of each waste (1:1, 1:3, 1:6) with tap water till the maturity. They reported that application of sewage and fertilizer waters especially at diluted treatments increased the N and P concentration of the plants. But oil and soap wastewater decreased their contents at all added concentrations. P content in different plants was promoted due to higher P contents of the fertilizer waste added to the soil. They also observed that lower dilutions of the fertilizer waste decreased K, Mg and N of the plants. The heavy metals, Fe, Mn, Zn, Cu, Pb, Co, Ni and Cd were enhanced either due to the source or the concentration of the applied wastes.

Ghosh *et al,* (1999) at Patna, observed the effect of various concentrations of distillery effluent on germination of pea, gram and black gram and reported that percentage germination increased up to 75% effluent in gram and pea and up to 50% in black gram. Plumule and radicle growth generally increased up to 50% effluent and than decreased while root- shoot ratio decreased with increasing concentration of effluent.

Ahmad *et al,* (2000) in Pakistan analyzed the fertilizer effluents, and evaluated the hazardous pollutants and studied their effects on crop plants and vegetables including spinach and fenugreek. The water samples were analyzed for pH, conductivity, hardness, alkalinity, dissolved solids, suspended solids, COD, chlorides, sulphates, sulphides, phosphates, silica, chlorine, ammonia, Ca, Mg and trace metals like Fe, Cd, Cr, Co, Cu, Pb, Mn, Ni, Sn and Zn. Effect of these effluents on crop plants and vegetables was observed and remedial measures for the hazardous pollutants of these effluents were also suggested by them. Kanwar and Sandha, during the same year while observing the waste pollution injury to vegetable crops reported that wastewater was contaminated with trace elements like Pb, Cd, Ni, Hg, U, Cu, Zn, B, Co, Cr, As, Mo, Mn etc. Many of these were non essential and toxic to plants, animals and human beings. They also reported the sensitivity of vegetable crops like lettuce, parsley, cabbage, onion, spinach, carrot, fennel, radish and tomato to water pollutants. They suggested that wastewater may be suitable for irrigation if the content of toxic elements were reduced considerably.

Chow *et al,* (2001) in Israel evaluated the potential of butter head lettuce and Chinese cabbage using municipal wastewater in deep flow technique. They had grown seedlings with three treatments: primary effluent, secondary effluent and half strength nutrient solution. Crop growth measurements, tissue minerals and quality of primary and secondary wastewater effluents were tested at 16 and 32 days after transplanting. Phytotoxicity symptoms on Chinese cabbage grown under primary as well as secondary effluents were also observed. They reported that butter head lettuce grew to maturity with little adverse effects. However, the yields of the two crops tested were lower than those grown in half strength nutrient solution. Primary effluent recorded the lowest yield among the three treatments.

Fasciolo *et al,* (2002) studied the effect of irrigation with treated municipal wastewater on garlic and onion. The two parameters evaluated were crop yield and crop microbiological quality for human consumption at different stages of growth and after harvest. Wastewater irrigation acted as well water with fertilizer, increasing the yields by 10% and 15% respectively in two crops tested, compared to irrigation with well water alone. Wastewater irrigated garlic reached sanitary acceptability at 90 days after harvest. Neither the wastewater irrigated crops nor the control crops were microbiologically acceptable for consuming raw.

Yusuf *et al,* (2003) worked out the levels of Cd, Cu and Ni in five edible vegetables, Talinum triangulare, Celosia trigyna, Corchorus olitorus, Venomia amygydalina and Telfaria accidentalis, and the soils in which the crops were grown, from three industrial and three residential areas of Lagos City, Nigeria. The results obtained for these three heavy metals from the industrial areas showed higher concentration than those of the residential areas. During the same year Baskar *et al,* (2003) observed eco-friendly utilization of distillery effluent in agriculture. Since the wastewater was of purely plant origin therefore contained large quantities of soluble organic matter and plant nutrients. It does not contain any toxic matter although it had excessive BOD, COD and EC which may be controlled either by proper dilution or by preplant application to give sufficient time for the natural oxidation of organic matter. They observed that distillery effluent significantly increased the yield of sorghum, wheat, maize, sugar cane, cotton, groundnut, sunflower, soybean, sugar beet, potato, forage crops and tree crops, but had adverse effect on legumes and no effect on rice.

Cui *et al,* (2003) observed the treatment and utilization of septic tank effluent to (i) use the nutrients in the treated effluents for hydroponic cultivation of some vegetables and also to purify the wastewater further by plant root system and to cultivate some ornamental plants and other commercial flowers in vertical flow constructed wetlands surface for getting its economic benefit. The results indicated that using treated effluents could reduce the nitrate content in vegetables. Results also indicated that vertical flow constructed wetlands surface could be used for ornamental plants or other commercial flowers. Also working on sewage Lone *et al,* (2003) conducted an experiment in Pakistan to investigate its effect and also of tube well water alone or mixtures of the two contaminated with heavy metals and micronutrients on some vegetables. The two waters affected the Ni, Cd, Cr and Pb contents in okra fruits and the maximum amount of heavy metals in spinach leaves was found in sewage water, and the lowest was with tube-well water. In spinach Ni content was maximum, followed by Pb, Cr and Cd and all micronutrients increased in leaves and fruits treated with sewage water. Ni, Cd, Pb and Cr were higher than the permissible limits in the edible parts with the application of both water treatments.

Samples of soil and plants were collected to assess the impact of sewage irrigation at Beijing by Liu *et al,* (2005). Concentrations of Cd, Cr, Cu, Zn, and Pb were determined to calculate the accumulation factor and to establish the basis for environmental protection and the suitability of sewage irrigation for particular land use in the urban–rural area. The metal enrichment factor (EF) of Cd (1.8), Cr (1.7), Cu (2.3), Zn (2.0), Pb (1.9) and the metal contamination factor (CF) of Cd (2.6), Cr (1.5), Cu (2.0), Zn (1.7), Pb (1.6) showed that the accumulation trend of the these toxic metals increased during the sewage irrigation as compared with lower reference values than other region in China and world average, and that pollution with Cd, Cu, Zn, and Pb was exacerbated in soils. It was pointed out that heavy metal transfer from soils to plants was a key pathway to human health exposure to metal contamination. However, with the expansion of urban areas around Beijing, soil inhalation and ingestion could become important pathways of human exposure to metal contamination. Also in the year 2005 at Karachi (Pakistan) a study was conducted by Midrar-ul-Haq *et al,* to observe the toxicity of Zn, Cu, Fe, Mn, Cd, Cr, Ni, Pb in different vegetables grown on contaminated sites of Korangi industrial area. They collected 40 effluent irrigated and 4 tube well irrigated samples and analyzed them. The values observed were compared with the toxic and excessive levels. The comparison showed that 100, 13, 18, 50, 93 and 50% of samples contained toxic or excessive levels of Cu, Mn, Cd, Cr, Ni and Pb respectively. The concentration of trace elements in effluent irrigated plants was more than those obtained in tube well irrigated plants and also higher than those generally reported.

Sharma *et al,* (2007) studied the effect of heavy metal contamination of soil resulting from wastewater irrigation at Varanasi (U.P.). Samples of irrigation water, soil, and edible part of the palak (*Beta vulgaris* L.var All green H1) were collected during the summer and winter seasons and analyzed for Cd, Cu, Zn, Pb, Cr, Mn and Ni. Heavy metals in irrigation water were below the permissible limits set by WHO set for agricultural use for these heavy metals except the Cd at various sites of suburban areas. Results of linear regression analysis computed to assess the relationship between individual heavy metal concentration in the vegetable sample and in soil showed that Zn in soil had a positive relationship with vegetable contamination during winter. Concentration of Cd, Cu, and Mn in soil and plant showed significant positive relationship only during summer. Concentration of Cr and Pb during the winter season and Zn and Ni during the summer season showed negative relationships between soil and plant contamination. They concluded that the use of treated and untreated wastewater has increased the contamination of Cd, Pb, and Ni in edible parts causing potential health risk in the long term use. Similarly case study was undertaken to assess the long- term effect of sewage irrigation on heavy metal content in soil, plants and ground water by Rattan *et al,* (2005). Agriculture land under Keshopur effluent irrigation scheme (KEIS) of Delhi, was selected where various cereals, millets, vegetables and fodder crops were commonly grown. Results showed that sewage effluents contained more P, K, S, Zn Cu, Fe, Mn and Ni as compared to groundwater. They reported that sewage irrigation for 20 years resulted in significant build-up of Zn (208%), Cu (170%), Fe (170%), Ni (63%) and Pb (29%) over adjacent tube well water irrigated soils, on the contrary Mn was depleted by 31%. While soils receiving sewage irrigation for 10 years exhibited significant increase in Zn, Fe, Ni and Pb, and only Fe in soils was positively affected by sewage irrigation after 5 years. Among these metals, only Zn in some samples exceeded the phytotoxicity limit. Risk assessment in respect of metal contents in some vegetable crops grown on these sewage-irrigated soils indicated that these vegetables may be consumed safely.

A study was carried out by Lokeshwari and Chandrappa, (2006) to assess the extent of heavy metal contamination of vegetation due to irrigation with sewage-fed lake water on agriculture land. Samples of water, soil and crop plants were analyzed for seven heavy metals, like Fe, Zn, Cu, Ni, Cr, Pb and Cd. The results showed the presence of some of the heavy metals in rice and vegetables, beyond the limits of Indian standards. Metal transfer factors from soil to vegetation were found significant for Zn, Cu, Pb and Cd. Comparing the results of heavy metals in water, soil and vegetation with their respective natural levels it was noted that impact of lake water on vegetation was more than of the soil. During the same year the crops analyzed in this study were heavily contaminated with Cd, Cu, Pb and Zn. This contamination was at its highest in maize and *tsunga*. *Tsunga* leaves contained 3.68 mg $kg^{-1}$ Cd, over 18 times the permissible level by the EU standards (0.2 mg $kg^{-1}$); Cu concentration was 111 mg $kg^{-1}$, 5 times (20 mg $kg^{-1}$); concentration of Pb was 6.77 mg $kg^{-1}$, over 4 times (50 mg $kg^{-1}$). Beans, maize, peppers and sugarcane also contained concentrations of heavy metals above the permissible limits. During the same year Muchuweti, study highlighted the potential risk involved in the cultivation and consumption of vegetables on plots irrigated with sewage sludge, a practice which may be responsible for ill health of the urban population after consuming these vegetables.

Effect of application of phosphatic fertilizers on Pb fractionation and phytoavailability in soil was studied by Zheng-miao, (2006) in China. It was found that the addition of single super phosphate (SSP), phosphate rock (PR), and calcium magnesium phosphate (CMP) significantly decreased the percentage of water-soluble and exchangeable (WE) soil Pb and also reduced the uptake of Pb, Cd, and Zn by the cabbage compared to control. The results showed that the level of 300 g P/m $^2$ soil was the most cost-effective application rate of P fertilizers for reducing the availability of Pb at the first stage of remediation, and that at this P level, the effect of WE fraction of Pb in soil decreased by the three phosphatic fertilizers followed the order: CMP (79%)>SSP (41%)>PR (23%). Effectiveness on the reduction of Pb uptake by cabbage was in the order: CMP (53%)>SSP (41%)>PR (30%). Thus the field trial showed that it was effective and feasible to reduce the Pb availability in soil and cabbage contaminated by mining tailings using phosphatic fertilizers and among the three phosphate rock would be most cost-effective.

Lonigro *et al*, (2007) at Barí (Italy) studied the vegetable crop under tertiary membrane filtered municipal wastewater as an alternative to natural fresh water. They considered membrane filtration as a viable technology to reclaim wastewater for irrigation, and the microbial and heavy metal impact on crops and soil was also studied by them. They tested the water which produced for drip irrigation on vegetable crops in succession processing tomato, fennel and lettuce and compared it with conventional water. Microbial content of the soil and the crops did not show much difference in relation to the two types of water and the measured values and filtered wastewater never caused an increase of bacterial concentration neither in the soil nor in edible part of the three crops. Therefore, they suggested that the tertiary filtered municipal wastewater can be a good alternative source of water for irrigation.

Khan *et al,* (2008) studied the health risks of heavy metals in contaminated food crops irrigated with wastewater a substantial buildup of heavy metals in wastewater–irrigated soils, collected from Beijing, China. Heavy metal concentrations in plants grown in waste water-irrigated soil were significantly higher than in plants grown in the reference soil, and exceeded the permissible limits set by State Environmental Protection Administration (SEPA) and the World Health Organization (WHO). During the same year a greenhouse pot experiment using lettuce (*Lactuca satuva* L.) as a representative vegetable was conducted by Khan *et al,* this study highlights the potential health risks associated with cultivation and consumption of leafy vegetables on wastewater-contaminated soils.

Kalavrouziotis *et al,* (2008) in a greenhouse, located at Agrinion, Greece, showed that treated municipal waste water (TMWW) had a residual effect with respect to some elements. Similarly, the TMWW increased significantly the heavy metal content in dry matter of the roots as, in Brussel sprouts Cd varied from 0.0083 to 0.78, Co 0.029 to 3.38 and Ni from 4.83 to 7.27 μg/g respectively while in Broccoli, Ni varied from 4.20 to 10.13 μg/g. TMWW also increased the accumulation of Fe in roots of Broccoli from 379.5 to 1022.0 mg/kg. However, the level of heavy metals in the edible plant parts were very high, varying in Broccoli, Ni 3.91–4.15 μg/g, and Pb 9.82–10.40 μg/g while in Brussels sprouts, Cd 0.8–1.17 μg/g, Co 2.35–2.70 μg/g, and Ni 5.70–6.17 μg/g. The increased heavy metal contents in the edible parts and the heavy FC and E. coli load of the TMWW constituted high health risk factor and therefore, in their opinion the TMWW studied cannot be used for irrigation of these vegetables unless it was treated properly.

Three vegetable sample (palak, lady,s finger, and cauliflower) were collected from the production and market sites from Varanasi (India) by Sharma *et al,* (2009), and tested for Cu, Cd, Zn and Pb. At market sites, the mean concentration of Cu in cauliflower, and of Zn and Cd in both palak and cauliflower had exceeded the prevention of food adulteration (PFA) standards. Cd concentration in vegetables tested from both production and market sites was many folds higher than the European Union (EU) standard. During the same year two vegetables were studied by Shahroz, at Aligarh with different concentrations of city wastewater to fenugreek and palak and found that wastewater improved the growth of these two vegetables. Similarly effect of wastewater on growth and productivity of chilli was studied by Iqbal, (2009) at Aligarh.

## 2.3 EFFECT OF WASTEWATER ON OTHER CROPS

Bishnoi and Gautam, (1991) while, taking 20, 50, 75 and 100% concentrations of dairy effluent studied some kharif crop plants at Bikaner (India). They reported that increasing effluent concentration decreased the percentage of germination. Misra and Behera, (1991) at Berhampur studied the paper mill effluents with four concentrations, 25, 50, 75 and 100% and observed that growth of rice seedlings was decreased with increase in time of exposure as well as concentration. Also in the year 1991, Neilson *et al,* (Canada) studied the response of wastewater to soil and sweet cherry while applying combinations of well water and municipal wastewater along with nitrogen @ 0, 68, 136 g as $NH_4NO_3$ $tree^{-1}year^{-1}$. Wastewater irrigation increased the leaf Mg and Ca and growth was also increased after two years but not after 5 years under wastewater. During the same year, Shukla and Pandey, at Raipur (India) soaked the seeds of maize, blackgram and greengram in 25, 50, 75 and 100% concentrations of wastewater from an oxalic acid manufacturing unit. Seed germination in these crops decreased from 100% under distilled water to 86, 32 and 55% respectively in 25% wastewater and 52, 12 and 15% respectively in 50% wastewater. In another study, also at Raipur, Goswami and Naik, (1992) evaluated the effect of fertilizer factory effluent on cluster bean and observed an improvement in chlorophyll content under 10% effluent whereas it was adversely affected under higher concentration and virtually a negative correlation was observed between the two. Shivhare and Pandey, (1995) also at the same place taking the effluent and crops like gram, moong, wheat, maize and paddy rice reported that percentage germination and seedling height was concentration dependent, with 40% showing a favourable effect while 100% proving toxic. Arora and Chhibba, (1992) collected samples of soil and leaf of wheat and rice from the farmers fields in Punjab (India) along a water drain in which the sewage water was discharged. The concentration of Cu and Fe in wheat leaves was higher while Mn and S was less but in case of rice leaves higher concentration of Zn, Cu, Fe as well as of Mn was observed.

As pointed out earlier, significant work on wastewater was also undertaken at Aligarh by Inam and his associates while working on different crops. Mention may be made of the work under taken at specially established research field adjacent to the Mathura oil refinery situated at a distance of 60 km from Aligarh. The work was carried out for fifteen years long and a continuous monitoring of heavy metals build up in the soil and crop produce was observed. Under this project Aziz *et al,* (1993a) studied the refinery wastewater on nitrate reductase activity (NR activity) of greengram. They reported that wastewater contained considerable amount of nitrate nitrogen, phosphate, potassium, calcium, chloride, sodium, sulphate as compared to ground water, and stimulated NR activity at all the sampling stages. Another field experiment at the same place was also conducted by them (1993b) on lentil. After two years of study, it was found that wastewater improved the growth. However, no significant difference in seed yield was observed during first year, but in the following year, the wastewater significantly increased the seed yield by 6.4% as compared to ground water. Aziz *et al,* (1994) further conducted a field trial and studied the growth and yield of triticale and wheat and also analysed the effluent, ground water and soil samples for various physico-chemical properties. Treated effluent increased the growth and yield of the two crops and triticale performed better than wheat. They again (1995) conducted a field experiment on four cultivars of wheat and reported improvement in growth and yield. In continuation, (1996a), Aziz *et al,* studied the long term effects of the same water on six crops and soil. Wastewater irrigation resulted in increased seed yield of wheat, triticale, chickpea, lentil and pigeon pea except that of summer moong, in which 16.6% more seed yield was obtained in fresh water. Berseem (*Trifolum alexandria* L.) was also grown for two consecutive years (1988-1989/90) by Aziz *et al,* (1996b). A perusal of the two years data revealed that treated wastewater, fertilizer treatment and their interaction improved the growth and yield. The increase in fresh yield due to treated wastewater treatment was 10.8, 20.8, 6.3 and 4.6% respectively in 1989-90. It was, therefore, concluded that Mathura Refinery treated wastewater may be used profitably for the cultivation of berseem.

While taking the same effluent earlier Inam *et al,* (1993) conducted a field experiment to compare the refinery treated effluent and groundwater on seedling emergence of triticales and wheat. No adverse effect on seedling emergence as compared to ground water was observed. In the following year, Samiullah *et al,* (1994) after two years work reported that refinery effluent was beneficial for wheat while Siddiqui *et al,* (1994) on the same water carried out a three year study and evaluated the moong. Contrary to earlier findings, shoot length, root length, nodule number, fresh and dry weight and yield, showed poor response under refinery wastewater as compared to ground water. Field experiments were also conducted by Aziz *et al,* (1999) to evaluate the certain-chemical properties of soil and on growth, yield and quality of corn and mustard. The pH of wastewater was close to neutral with higher amount of nitrogen, potassium, phosphate, sodium, chloride, calcium, carbonates, and bicarbonates and suspended and dissolved solids when compared with fresh water. Soil receiving the waste water showed no significant changes in water soluble salts, electrical conductivity, cation exchange capacity, pH, total organic carbon etc. Waste water irrigation enhanced the growth and yield of both crops. A split plot field experiment was conducted by Shah *et al,* (2005) to study the comparative effect of sewage wastewater and ground water and nitrogen doses $N_{60}$, $N_{90}$, $N_{120}$, $N_{150}$, $N_{180}$ and $N_{210}$ on the performance of triticale, TL-419. Sewage water resulted in increased growth, yield, protein and carbohydrate content. Among nitrogen doses, $N_{120}$ proved optimum and sewage wastewater met the irrigational quality characteristics, being well within the permissible limits of Indian standards. Tabassum *et al,* (2007) also at Aligarh studied the utility of city wastewater (50% and 100%WW) as a source of irrigation and cultivated mustard. They also supplied different doses of K ($K_0$, $K_{10}$, $K_{20}$ and $K_{30}$ kg $ha^{-1}$) with a uniform basal dose of 80 kg N $ha^{-1}$and 30 kg P $ha^{-1}$. Wastewater gave better response for leaf area, photosynthetic rate, stomatal conductance, photosynthetic water use efficiency, leaf NPK contents and seed yield. They also concluded that physico-chemical characteristics of wastewater met the irrigational quality requirements and most of them were within the permissible limits.

Kannabiran and Pragasam, (1993) at Pondicherry (India) observed that the seeds of black gram failed to germinate in undiluted distillery effluent. At 75% concentration, radicles emerged, but further growth was inhibited from the third day, while at 50% the roots were very short and devoid of laterals, whereas at 25%

concentration roots showed few laterals. 10% showed comparatively lower value than obtained under control, 1% and 5% concentrations. Higher germination percentage and increased chl-a, chl-b and total chlorophyll contents were recorded in 2.5% and carotenoid contents were maximum in 5%. During the same year Tiwari *et al,* (1993) from Varanasi (India) reported the effect of distillery effluent on Indian mustard. Seed germination and early growth was decreased with increasing effluent concentration and at higher concentration it was completely suppressed. Vijayarengan and Lakshmanachary, also in the year 1993, while using textile mill wastewater on green gram at Annamalainagar (India) reported that germination percentage decreased with increase in concentration. Wastewater at 5% and 10% concentration increased the growth and dry weight of the seedlings while higher concentration proved deleterious.

Goyal *et al,* (1995) at Hissar (India) applied distillery wastewater on moong, which increased the dry matter production and N and P uptake but dry matter was decreased markedly when quantity of wastewater was increased. During the same year Cisneros *et al,* tested wastewater of Mexico valley, which was a mixture of domestic, industrial discharges and rainfall. Crop yields were above the national average particularly in case of maize and lucerne. Singh *et al,* (1995) at Rishikesh (India) in a field study irrigated the sorghum, maize and cowpea with treated sewage water and effluent from a pharmaceutical factory or a tube well water applying 0, 50, 100 or 150 kg N + 60 kg P + 40 kg K $ha^{-1}$ or without fertilizer. Sorghum and maize fodder yields were maximum with treated sewage and minimum with tube well water. They also reported that fertilizer application increased the fodder yield. Response of NPK was consistent in tube well irrigated maize and sorghum but variable in treatments irrigated with treated sewage or factory effluent. Cowpea fodder yield was not affected by irrigation source or fertilizer application. Also in the year 1995, Shukla and Moitra, at Shilong (India), soaked the seeds of gram, greengram, maize and rice, in 0, 25, 50, 75 and 100% concentrations of steel plant wastewater. Seed germination and seedling growth of all the crops studied decreased with increase in wastewater concentration.

Anjana and Rao, (1996) at Jabalpur made an investigation on the effect of water coming out of treatment plant of Shaw-Wallace gelatin factory, dicalcium phosphate plant and water from Narmada river and found that percentage germination and seedling growth of some crops were improved. Elsokkary and Sharaf, (1996) at Nile delta (Egypt) studied two cultivated regions representing alluvial (Region No.1) and Lacustrine (Region No.2) soils. The source of irrigation water at Region No.1 was a mixture of agricultural drainage and domestic effluents and that at Region No.2 it was a mixture of agricultural drainage, domestic and industrial effluents. However, rain was another source of water in the winter season. Samples of water, soils and different plant species were collected during two seasons. The concentrations of Zn and Cd in the waters of the two regions were, on an average, 20 and 11 mg $L^{-1}$ at Region No. 1 and 16.0 and 12 mg $L^{-1}$ at Region No.2 respectively. Metal contents in leaves of plant species varied markedly and similarly the capacity of plant species to take up metal ions from the soil also varied. The resulted bioaccumulation ratios of Zn in plants followed the sequence: chard > spinach > lettuce > parsley > roquette >coriander > clover. Working on different concentrations Kumar *et al,* (1997) at Bhavnagar (India) moistened the seeds of green gram and black gram with 10, 25, 50, 75 and 100% of dairy effluent and observed a gradual decrease in seed germination percentage, seedling growth and pigment contents at 25% concentration.

Bera and Saha, (1998) at Mohanpur (India) studied the effect of different concentrations of tannery effluent on pigeon pea and rice and found that seedling growth was stimulated under 10% and 5% concentrations. Paliwal *et al,* (1998) examined the effect of different concentrations of sewage water on growth, biomass and nutrient accumulation growing under nursery conditions. Biomass and leaf-area of the seedlings treated with 50% sewage showed an increase over control. Photosynthetic pigments and total soluble protein decreased with increase in concentration. At higher concentrations, the accumulation of nitrogen and phosphorus in different components of seedlings was in order: root > stem > leaves. The accumulation of heavy metals resulting from short term application of sewage water was in order: Mn > Zn > Pb > Cu. The sewage water concentration at 75% and 100% retarded the growth of seedlings and in their opinion only the 50% dilution was suitable. Yamada *et al,* (1998) in Japan, sprayed wastewater obtained from disinfection of rice seeds containing two fungicides viz. pofurazoate and oxolinic acid and an insecticide fenitrothion on soil in nursery boxes. There was no appreciable effect on seedling emergence using dilutions 0, 2, 5, 10 or 20 times. However, seedling growth was suppressed at dilution rates lower than 10 times.

Adjei and Rechcigl, (2002) while taking bahiagrass compared the agronomic value of aerobically digested slurry biosolids, lime stabilized slurry biosolids, lime-stabilized cake biosolids and ammonium nitrate applied to supply 90 or 180 kg N $ha^{-1}$ vs. unfertilized control. It was observed by them that the slurries and ammonium nitrate gave 50% or more forage and higher spring crude protein (CP) concentration. The CP was improved with ammonium nitrate in early spring, after which, there were no consistent differences in CP or in vitro organic matter digestion. They also noted that forage was deficient in K and Mn in summer across treatments. Lime stabilized biosolids could boost bahiagrass production in Florida because it was lower in pathogens, inexpensive, and provided lime as well as the organic matter. Singh *et al,* (2002) at Lalkua (India) assessed agro potentiality of the effluent coming out from century pulp and paper mill, on wheat crop grown in two soils differing in texture under different concentrations of effluent. Diluted effluent increased the chlorophyll content, plant height, shoot and root biomass, grain yield, protein, carbohydrate and lipid contents in grains while undiluted effluent caused inhibition in plant growth resulting in decreased yield. During the same year Zein *et al,* in Egypt investigated the effect of (Wi) Nile water, good quality water (Wi) mixed water, 50% Nile water + 50% WW and (Wa) WW, poor quality water, on Pb, Mn, Cu, Zn, Cd and Ni contents and four sugar beet cultivars. Maribo cv. recorded the maximum sugar yield at two seasons for Wi and W2 while local cultivar was superior in its root yield for these water quality treatments in the first season, while Maribo cv. was superior under (W2) and (Wa) during second season.

Yadav *et al,* (2002) at Haryana (India) compared the spatial distribution of N, P, K and micronutrients and toxic elements in the top 0.6 m of an alluvial soil along with their associated effect on the composition of crops and ground water after about three decades of irrigation of domestic sewage as a function of distance from the disposal point. Use of sewage for irrigation in various proportions improved the organic matter to 1.24-1.78% and fertility status of soils especially down to a distance of 1 km along the disposal channel. Build up in total N was up to 2908 kg $ha^{-1}$, available P (58 kg $ha^{-1}$), total P (2115 kg $ha^{-1}$), and available K (305 kg $ha^{-1}$) and total K (4712 kg $ha^{-1}$) in surface 0.15 m soil. Vertical distribution of these nutrients also varied, with most accumulations occurring at 0.3 m. Traces of $NO_3$-N (up to 28 $mgL^{-1}$), Pb (up to 0.35mg $L^{-1}$) and Mn (up to 0.23 mg $L^{-1}$) could also be observed in well waters near the disposal point thus indicating initiation of ground water contamination. However, the contents of heavy metals in crops collected from the area were below the permissible critical levels. Though the study confirmed that the domestic sewage can effectively increase the water resource for irrigation but there is a need for its monitoring.

A pot experiment was conducted by Javid *et al,* (2003) at Aligarh in a net house to observed the effect of sewage wastewater on growth, NPK content, yield and grain quality of wheat (*Triticum aestivum* L.) cv. HD-2329. It promoted the growth and yield and nitrogen, phosphorus and potassium level was higher in wastewater irrigated plants while protein and carbohydrate was lower in grains obtained under wastewater application. Sewage wastewater met the irrigational quality requirements as its physico-chemical characteristics were within the permissible limits. McIntosh and Fitzsimmons, (2003) at Arizona (USA) studied the coastal aquaculture, contribute to eutrophication of receiving waters. Current practices, however, do not provide an additional use for effluent water. Nitrogen, phosphorus and other effluent elements could be valuable plant nutrients. Inflow and effluent water from an inland, low-salinity shrimp farm were monitored. Analysis after two weeks included total nitrogen, ammonia-nitrogen, nitrite-nitrogen, nitrate-nitrogen, total phosphorus, reactive phosphorus, alkalinity, COD, BOD, TSS and volatile suspended solids (VSS), as well as temperature, salinity, DO and pH. Alkalinity and total nitrogen decreased during the in-pond residency and the other parameters increased while in ponds. The potential benefit of nutrient enriched wastewater to irrigate field crops was substantial, supplying about 20 and 31% of the necessary nitrogen for wheat production.

Emongor and Ramolemana, (2004) studied that Botswana being semi-arid and arid country, the provision of drinking water for agriculture is becoming increasingly difficult and costly. Therefore, the techniques such as drip irrigation, sensors, growing plants with low water requirements, timings and scheduling of irrigation to the growth needs or the plant, mulching, and establishing a minimum water quality standard for horticultural crops must be used to stretch agricultural water supplies. Recycling agricultural water and using treated municipal sewage was a viable option in their opinion. Agricultural wastewater and sewage often contain significant quantities of heavy metals and other substances that may be harmful to people but beneficial to horticultural crops. However, in their opinion before sewage effluent can be used for cultivation, research must be undertaken to determine whether there is accumulation of heavy metals and faecal coliforms in the edible portion which may be detrimental to human health. They also suggested that 15-20 years later research must be undertaken to assess the impact of sewage effluent on soil physical, and chemical properties.

Lime-stabilized urban wastewater on barley (hordeum vulgare L.cv. kaya) has been studied by Burun *et al,* (2006) at Turkey during two years. The effect of 3-25 ton $da^{-1}$ wastewater application was also investigated. In addition to these, the effect of different wastewater application in four levels ranging from 6 to 24 was determined with the treatment of 20 kg $da^{-1}$ 15:15:15 NPK composed fertilizer. Significant increases on the P and K contents of soils and N, P, K, Ca, Fe, Mn, Cu and Zn contents of leaves were observed. Increasing the doses wastewater applications affected the yield components positively. As a result of high dose application, a significant yield increase was also observed. When the wastewater was applied to soil, grain yield and nutrients content of barley increased considerably. There was no negative effect on protein content either. In their opinion, stabilized wastewater can be used under controlled conditions in agriculture areas.

Solis *et al,* (2006) studied the Chinampas Xochimilco located in southern Mexico City and represent the reminiscence of the pre-Columbian farming system, the "chinampas" agriculture. "Chinampas" are island plots surrounded by a canal network. Various agricultural species, including vegetables, cereals and flowers, were produced in the "chinampas". In order to characterize the quality of Xochimilco, water used for irrigation, spatial and temporal contaminant indicators such as microorganisms and heavy metals were investigated. Fecal coliforms, fecal enterococcus were also analyzed plus the heavy metals like Fe, Cu, Zn and Pb. The more contaminated sites coincide with the heavily populated areas. Seasonal variation of contaminants was observed, with the higher bacterial counts and heavy metal concentrations reported during the rainy season.

Soil and rice plants collected from a paddy field in Lechang lead–zinc mine area, Guangdong Province, China were analyzed by Yang *et al,* (2008) and their potential ecological impacts to local people and livestock were observed. Paddy soils were contaminated with Cu and Zn and the two metals in soils had low bio-available fractions for paddy plants, animals and humans. Generally, the concentration of copper and zinc was root > straw > stalk > grain with hull > grain without hull (i.e. unpolished rice) and in the normal range indicating no ecological risk for local livestock and residents. Growth and productivity of sweet sorghum [*Sorghum bicolor* (L.)] var. Keller, under two different irrigation methods the conventional surface drip method (two treatments) and the subsurface drip method in a dry year in Central Greece, as an energy crop for the production of bio-ethanol were studied.

## 2.4 HEAVY METAL ACCUMULATION AND THEIR REMOVAL BY PLANTS

The accumulation of heavy metals in agricultural soils and plants and their removal is of increasing concern due to the food safety issue and potential health risks as well as its detrimental effects on soil ecosystems, ground water and food chains. It also poses potential barriers for international trading of foodstuffs. Regulatory frameworks and guidelines for heavy metals in the environment and food stuffs have been developed in many countries around the world including India but their enforcement is broadly related. Some of the references are briefly mentioned here. The effect of irrigation with secondary treated municipal effluent on the accumulation of heavy metals was investigated by Smith *et al,* (1996) at Wodonga. Similarly heavy metals were measured in bottom sediments, water and *Typha angustifolia* and *Potamogeton pectinatus* in Sultan Marsh by Demirezen and Aksoy, (2004) and by Mireles *et al,* (2004) in plants and soil irrigated with wastewater from Mexico City. The concentrations of lead, zinc, copper and cadmium accumulated by 12 emergent-rooted wetland plant species including different populations of *Leersia hexandra, Juncus effusus* and *Equisetum ramosisti* were investigated in field conditions of China by Deng *et al,* (2004) while Tani and Barrington, (2004) worked out the environmental risks of irrigating crops with treated wastewater, to quantify heavy metals uptake by buckwheat (*Fagopyrum esculent* L.) plants. Likewise Cd and Pb from soils to the edible parts of six vegetable species were studied by Wang *et al,* (2006) in fields at Fujian southeastern China, and forage crops were studied by Grytsyuk *et al,* (2006) Numerical model for heavy metal transport and its uptake by vegetables in the root zone was given by Verma *et al,* (2007) where simulation of cadmium uptake by radish, carrot, spinach and cabbage was observed. A pot experiment was conducted by Rahaman *et al,* (2007) at Bangladesh Agricultural University, for uptake of Cd by rice plant and Singh and Agarwal, (2007) determined the Pb, Cr, Cd, Cu, Zn and Ni concentration of soil by mixing sewage sludge. Sewage irrigation on the uptake and translocation of Hg in corn plants (*Zea mays*) was carried out by Rothenberg *et al,* (2007) while Al-Lahham *et al,* (2007) investigated the extent of translocation of heavy metals to tomato (*Solanum lycopersicom* L cvs), at Amman–Jordan. An experiment was conducted by Nair *et al,* (2008) in a hydroponics setup to determine the suitability of zinc and copper contaminated wastewater for edible crops silver beet and during the same year Arora *et al,* studied Fe, Mn, Cu and Zn in vegetables irrigated with wastewater. Recently vegetable species (Chinese leek, pakchoi, carrot, radish, tomato and cucumber) were also grown to study the accumulation of Cd under different conditions by Yang *et al,* (2009). Similarly distribution of Cu, Cd, Cr, Zn, Fe, Ni, Mn and Pb in wheat and mustard plants was reported by Chandra *et al,* (2009) while in a field experiment by Jambhulkar and Juwarkar, (2009) at Nagpur, India, accumulation of some heavy metals in vegetation was reported.

Removal of heavy metals from industrial wastewater is of primary importance. This is because contamination of wastewater by heavy metals is a very serious environmental problem. The use of natural material for heavy metal removal is becoming a general practice in many countries. Therefore, research into the utilization of agricultural by products as absorbents for the removal of heavy metals from aqueous medium has been on the increase. This is because the agricultural by products are naturally occurring, hence they are available at little or of no cost. The application of low cost natural absorbents including carbonaceous materials, agricultural products and by-products has been investigated in many studies. For this purpose studies were carried out by several authors for heavy metal removal. Ability of cassava waste biomass to remove Cu (II) and Zn (II) from single-ion solution and wastewater was investigated by Horsfall *et al,* (2003). Cassava waste biomass saturated with metal ions showed remarkable ability for metal recovery, and can be used repeatedly for removal of heavy metals. Angelova *et al,* (2004) investigated the bio-accumulation and distribution of heavy metals in fibre crops like flax, cotton and hemp which may remove considerable quantities of heavy metals from soil with their root system and can be used as potential crops for cleaning the soil. The kinetics of sorption and intraparticulate diffusivities of Zn, Cd and Pb using maize cob was studied by Abia *et al,* (2005). Similarly a study was carried out by Azmat *et al,* (2007) on contaminated sewage sludge collected from Karachi city, where onion, spinach and turnip were cultivated. Results showed that concentration of metals in soil decreased by bio-sorption of toxic metal on seaweed. Nile Rose Plant was used by Abdel-Ghani and Elchagha, (2007) to study adsorption of several cations like $Cu^{2+}$, $Zn^{2+}$, $Cd^{2+}$ and $Pb^{2+}$ from wastewater. The removal order was found to be $Pb^{2+} > Zn^{2+} > Cu^{2+} > Cd^{2+}$. The kinetics was studied by Igwe *et al,* (2008) for biosorption experiments using coconut fiber for As (III), Hg (II) and Pb (II) ions. The maximum adsorption capacity was found to be for Pb (II) followed by Hg (II) and As (III).

From the above review of literature it may be inferred that there was sufficient scope to undertake the turnip cultivation study under wastewater as in India now a days most of the vegetables are grown with waste water as it is easily available and also rich in mineral nutrients.

## CHAPTER 3

# MATERIALS AND METHODS

### 3.1 WORK PLAN: AN OVERVIEW

In order to assess the suitability of using treated municipal wastewater i.e. effluent from Sewage Treatment Plants (STPs) for growing turnip (*Brassica rapa* L. var. Purple top) along with uptake of heavy metals by the roots and their subsequent translocation in leaves was monitored at different stages of growth. Experiments were conducted in pots during the rabi (winter, September–November.) seasons of 2006-2007 and 2007-2008 in the Department of Civil Engineering, Environmental Engineering Laboratory at IIT Roorkee, India. Pots were watered with (i) tap water containing varying amount P levels at constant levels of N and K and concentrations of 38 million liters per day (ML/d) STP, treated water mixed with tap water in ratios (3:1, 1:1, 1:3) (ii) tap water containing varying amount of K levels at constant concentration of N and P and different concentrations of 38 ML/d STP, treated water mixed with tap water in ratios (3:1, 1:1, 1:3) supplemented with different doses of N, P and K. (iii) Sewage Treatment Plant (STP) namely 34 ML/d treated water mixed with tap water in ratios ( 1:1, 1:0) with different amount of P and at constant levels of N and K (iv) Sewage Treatment Plant (STP) namely 34 ML/d treated water mixed with tap water in ratios ( 1:1, 1:0) with different amount of K and at constant levels of N and P. Details are given in section 3.3.

### 3.2 AGROCLIMATIC CONDITIONS OF ROORKEE

Roorkee city is situated in Uttarakhand state, 172 Km away from Delhi the capital of India. It is located at $29^0 52'$ latitude and $77^0 51'$ longitude and has an elevation of 268m. Summers start in late March and go on until early July, with varying average temperatures indicated in fig. 1. The monsoon season starts in July and goes on until October, with torrential rains, due to the blocking of monsoon clouds by the Himalayan range. The post monsoon season starts in October and goes on until late November, with average temperature sliding down up to $7^0$C. Winters start in December, with low temperature close to $4^0$C and frequent cold waves due to the cold blowing from the Himalayas. The total annual rainfall is about 2600 mm.

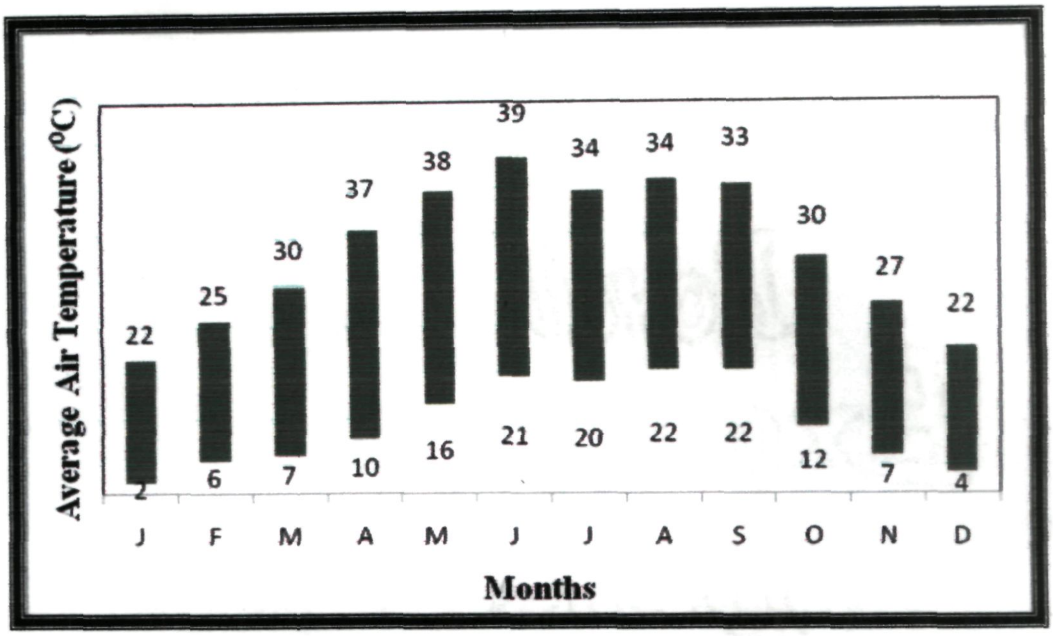



**Fig: 1. Monthly temperature variation at Roorkee**

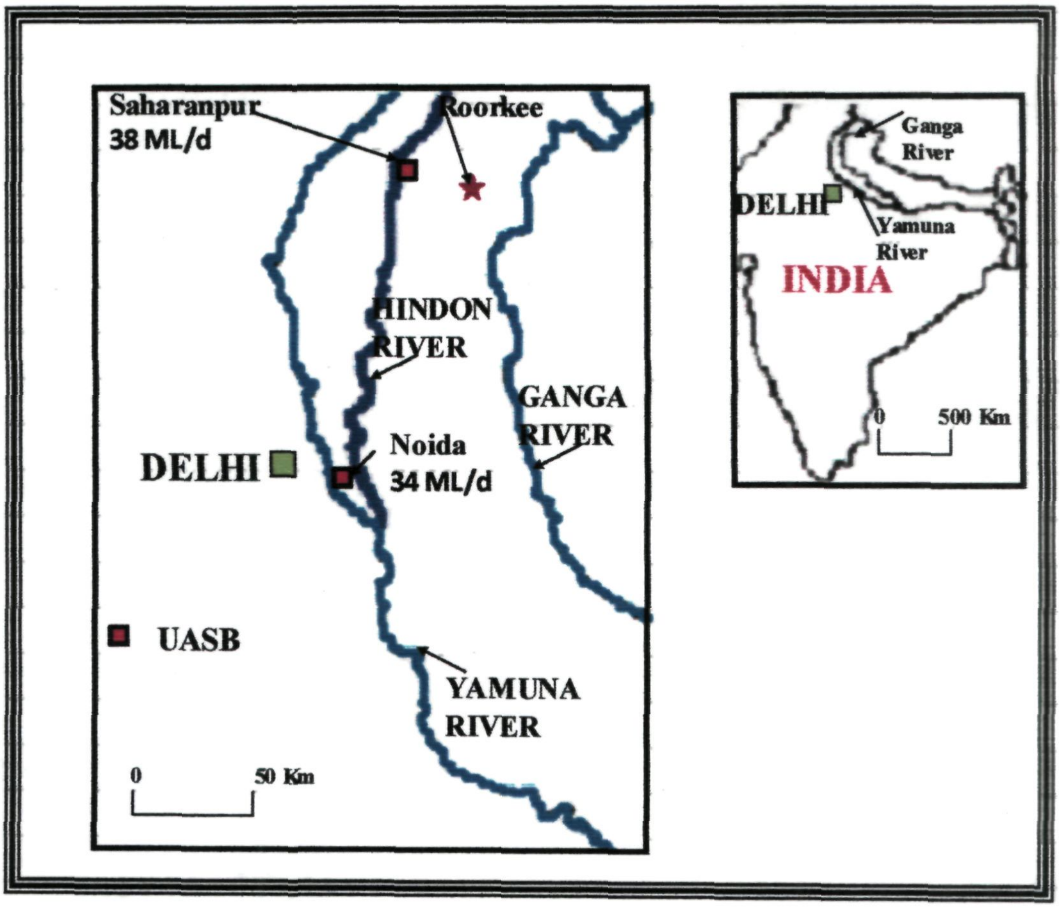



**Fig: 2. Locations of STPs selected for the study with their treatment capacities**

## 3.3 EXPERIMENTS

### 3.3.1 *Preparation of pots*

Turnip was grown in 72 pots for experiment-I and 72 pots for experiment-II. Pots were prepared and monitored during September-November 2006. Again these pots were prepared and monitored in September-November 2007. The composition of water used for watering these pots was varied. Details of the variables are given in tables 1-4. Pots were further classified in to eight sets according to the nature of water which was used for watering. One set of pots was watered with tap water and other set was irrigated with waste water mixed with tap water, and wastewater alone (with and without dilution) amended with nutrients. Pots of 25 cm diameter filled with 5 kg soil and mixed with 2% organic manure were used for experiments. Sufficient quantity of tap water was added to each pot to provide necessary moisture for germination. NPK doses were applied 24 hours in advance to avoid seed injury. Experiment I and II (Table 9, 10) were conducted based on simple randomized block design while the III and IV were based on factorial randomized block design (Table 11, 12)

In the month of September, 10 seeds of turnip (*Brassica rapa*) were sown manually at equivalent distances in each pot. The pots were kept in open. Each pot was initially watered with 200 ml tap water up to germination. Seeds germinated within 10 days. After wards thinning was done to maintain a single plant in each pot. Sampling for the study of growth was done after 40, 55 and 70 days after sowing (DAS) in each experiment. Pots were watered daily with 100 ml of designated water treatments (Table 1-4). Each set contained nine pots. Three plants were carefully uprooted at 40 DAS, with minimum damage to root. Out of remaining six, three pots were harvested after 55 days and remaining at 70 DAS. Uprooted plants were analyzed for root diameter, number of leaves, plant height, plant fresh weight, plant dry weight, leaf fresh weight, leaf dry weight, root fresh weight, root dry weight and metal accumulation in leaves and roots. Urea, single super phosphate and potassium chloride were added in appropriate amount to meet designated loading of N, P and K. The treatment $N_0P_0K_0$ does not imply that the wastewater is devoid of nutrients. It implies that the water/wastewater have not been supplemented with additional amount of N, P and K. The watering conditions have been labeled as treatment.

Fig: 3. Plant 40 DAS

Fig: 4. Plant 55 DAS

Fig: 5. Plant 70 DAS

**Fig: 3-5 Showing growth at 40, 55 and 70 DAS of turnip in pots and single plant after sampling**

### 3.3.2 *Experiment-I (15th September -24th November, 2006)*

Wastewater samples were collected from Upflow Anaerobic Sludge Blanket (UASB) based 38 ML/d Sewage Treatment Plant located at Saharanpur (U.P.) India. The sowing was done on 15th September, 2006. Pots were watered with (i) tap water alone, (ii) tap water supplemented with varying amount of N, P and K (Treatment No. $T_2$-$T_4$, Table 1) and (iii) tap water mixed with varying amount of treated sewage water without adding urea, super phosphate and potassium chloride ($T_5$-$T_8$). Thus there were eight sets of pots, out of which four sets received different concentrations of wastewater ($T_5$-$T_8$), and remaining four sets received nutrient amended tap water ($T_2$-$T_4$).

**Table: 1 Scheme of treatments applied in Experiment-I**

| Treatment No. | Tap water (TW) Nutrient loading kg/ha | | | Tap water signature | Treatment No | wastewater (WW) Nutrient loading kg/ha | | | Wastewater signature |
|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | | | N | P | K | |
| $T_1$ | 0 | 0 | 0 | $TW+N_0P_0K_0$ | $T_5$ | 0 | 0 | 0 | $WW_{25}+N_0P_0K_0$ |
| $T_2$ | 50 | 12.5 | 25 | $TW+N_{50}P_{12.5}K_{25}$ | $T_6$ | 0 | 0 | 0 | $WW_{50}+ N_0P_0K_0$ |
| $T_3$ | 50 | 25 | 25 | $TW+N_{50}P_{25}K_{25}$ | $T_7$ | 0 | 0 | 0 | $WW_{75}+ N_0P_0K_0$ |
| $T_4$ | 50 | 50 | 25 | $TW+N_{50}P_{50}K_{25}$ | $T_8$ | 0 | 0 | 0 | $WW_{100}+ N_0P_0K_0$ |

The signature implies

$WW_{25}$: 75% tap water and 25% wastewater (3:1)

$WW_{50}$: 50% tap water and 50% wastewater (1:1)

$WW_{75}$: 25% tap water and 75% wastewater (1:3)

$WW_{100}$: 0% tap water and 100% wastewater (0:1)

It may also be pointed out here that in this experiment varying doses of phosphorus were given ($P_0$, $P_{12.5}$, $P_{25}$, $P_{50}$) while N (50 kg/ha) and K (25 kg/ha) fertilizer was common in all four treatments which was applied one day before sowing to avoid seed injury. The NPK applied to pots was calculated on the basis that one hectare land contains $2.24\times10^6$ kg effective soil (Gupta, 2004).

### 3.3.3 *Experiment-II (16th September - 25th November, 2006)*

This experiment was conducted simultaneously with experiment-I. Sowing method, sources of irrigation water, and irrigation schedule were the same as in experiment-I. However, difference of one day was kept from sowing, sampling and harvesting for getting sufficient working time and space. The composition of water and wastewater used for watering the pots and the scheme of treatments is given in table 2. In this experiment, pots were watered with (i) tap water alone (ii) tap water supplemented with nutrients N,P and K ($T_{10}$-$T_{12}$) and (iii) wastewater with four dilutions and also supplemented with N, P and K ($T_{13}$-$T_{16}$).

**Table: 2 Scheme of treatments applied in Experiment-II**

| Treatment No. | Tap water (TW) Nutrient loading kg/ha | | | Tap water signature | Treatment No. | Wastewater (WW) Nutrient loading kg/ha | | | Wastewater signature |
|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | | | N | P | K | |
| $T_9$ | 0 | 0 | 0 | $TW+N_0P_0K_0$ | $T_{13}$ | 12.5 | 12.5 | 12.5 | $WW_{25}+N_{12.5}P_{12.5}K_{12.5}$ |
| $T_{10}$ | 50 | 25 | 12.5 | $TW+N_{50}P_{25}K_{12.5}$ | $T_{14}$ | 25 | 25 | 25 | $WW_{50}+N_{25}P_{25}K_{25}$ |
| $T_{11}$ | 50 | 25 | 25 | $TW+N_{50}P_{25}K_{25}$ | $T_{15}$ | 50 | 50 | 50 | $WW_{75}+N_{50}P_{50}K_{50}$ |
| $T_{12}$ | 50 | 25 | 50 | $TW+N_{50}P_{25}K_{50}$ | $T_{16}$ | 100 | 100 | 100 | $WW_{100}+N_{100}P_{100}K_{100}$ |

In this experiment there were two variations one was the varying doses of K while P and N dose was uniform under tap water treatments. The second was the variations in NPK doses under wastewater signature (Table 2).

### 3.3.4 *Experiment-III (15th September - 24th November, 2007)*

This experiment was carried out in the rabi season of 2007-2008. The aim of this experiment was to study waste water discharged from another STP discharging 34 ML/d effluent and located at Noida (U.P.). Another variation in this study was reduction in waste water concentration levels up to two as 100%ww proved better based on the findings of earlier two experiments. Thus only two concentrations of (50%, and 100%)

wastewater, were included without tap water treatment with uniform basal dose of nitrogen (50 kg N/ha), and potassium (25 kg K/ha) and again varying amount of phosphorus ($P_0$, $P_{12.5}$, $P_{25}$, $P_{50}$) in 50% as well as 100%ww. The crop was sown on 15th, September, 2007 and harvested on 24th November, 2007. The scheme of treatments of wastewater used for watering the pots and fertilizer doses is given in table 3.

### 3.3.5 *Experiment-IV (16th September -25th November, 2006)*

This experiment was carried out along the Experiment-III in the rabi season of 2007-2008. The aim of this experiment was to study the effect of 50% and 100% wastewater with uniform basal dose of nitrogen @50 kg N/ha ($N_{50}$) and phosphorus @25 kg P/ha ($P_{25}$) and different doses of potassium ($K_0$, $K_{12.5}$, $K_{25}$, $K_{50}$) in both 50% as well as 100%ww. The sampling was done at three stages i.e.40, 55 and 70 days after sowing. All the cultural practices remained the same.

**Table: 3 Scheme of treatments applied in Experiment-III.**

| Fertilizer Treatments (Kg NKP ha$^{-1}$) | Irrigation water treatments | | Remarks (NKP kg/ha)* |
|---|---|---|---|
| | 50%WW | 100%WW | |
| $N_0K_0$ $P_0$ (Control) | + | + | No fertilizer |
| $N_{50}K_{25}$ $P_{12.5}$ | + | + | (50+25+12.5) |
| $N_{50}K_{25}$ $P_{25}$ | + | + | (50+25+25) |
| $N_{50}K_{25}$ $P_{50}$ | + | + | (50+25+50) |

A uniform basal dose (50 kg N and 25 kg K ha$^{-1}$) was applied one day before sowing.

**Table: 4 Scheme of treatments applied in Experiment-IV.**

| Fertilizer Treatments (Kg NPK ha$^{-1}$) | Irrigation water treatments | | Remarks ( NPK kg/ha) |
|---|---|---|---|
| | 50%WW | 100%WW | |
| $N_0P_0K_0$ (Control) | + | + | No fertilizer |
| $N_{50}P_{25}K_{12.5}$ | + | + | (50+25+12.5) |
| $N_{50}P_{25}K_{25}$ | + | + | (50+25+25) |
| $N_{50}P_{25}K_{50}$ | + | + | (50+25+50) |

A uniform basal dose (50 kg N and 25 kg P ha$^{-1}$) was applied one day before sowing.

### 3.4 GLASSWARE AND CHEMICALS

Glassware procured from Borosil (India) were immersed overnight in dilute HCl (0.1N), washed with tap water and then with distilled water. Cleaned glassware were kept in an oven at 100°C for 2 hours for drying. Analytical grade (AR) or laboratory grade (LR) chemicals were used supplied by SD Fine Chem., India. Whatman filter papers (Whatman 44, ashless) were first soaked in distilled water to remove any soluble material present and then kept in temperature controlled oven at 100°C for an hour. The dried filter papers were stored in desiccators and used in analysis.

### 3.5 WATER ANALYSIS

Equipment/instruments listed in table 5 were used for parametric determinations. Water and wastewater samples were analyzed for parameters listed in table 6 (APHA 1998). Samples for heavy metal analysis were collected in plastic bottles containing 2 ml $HNO_3$. For coliform analysis samples were collected in sterilized bottles. Bulk of samples were collected in plastic bottles and transported in ice-box. Procedures listed in Standard Methods (APHA, 1998) were followed for sample collection, preservation, transportation and analysis. COD was determined by closed reflux method. BOD at 3 days and at 27°C was analyzed by BOD bottles equipped with pressure sensors and with inductive stirring system. A substrate prepared by mixing 150 mg each of glucose and glutamic acid (APHA, 1998) was used as check solution for standardization. DO was analyzed with Aqualytic OX 24 DO meter. Measurements were made in triplicate. Data presented is the average or the range of value. A spectrophotometer (DR/4000, Hach, USA,) was used for measuring nitrate nitrogen, ammonical nitrogen, and phosphorus. Hardness, alkalinity, chloride, calcium and magnesium were estimated by titration. Sodium and potassium were measured by flame photometer. While sulphate was determined by turbidimetric method. Total coliform and fecal coliform were determined by multiple tube fermentation technique. Samples collected for heavy metal analysis were immediately acidified at sampling point to pH $<2.0$ by adding $HNO_3$ to prevent the precipitation of metals. Acidified samples (350 ml) were digested with $HNO_3$ and filtered. The filtrate was aspirated in to Atomic Absorption Spectrophotometer (Model GBC Avanta M) for the analysis of Cd, Cr, Ni, Fe, Cu, Mn and Zn.

**Table: 5 Instruments and methods used in the experimentation**

| Parameter | Technique/Instrument Model |
|---|---|
| pH | pH meter, Cyberscan 5 -1 0 pH |
| Turbidity | HACH, 2100 AN Turbidity meter |
| Conductivity | Conductivity meter |
| DO | DO meter, HQ 10 Hach portable LDO$^{TM}$ & aqualytic OX 24, Germany |
| BOD | BOD pressure sensor and inductive stirring system, aqualytic GmBH & Co. Germany |
| COD | COD analysis system, (i) Hach COD reactor model 45600 (ii) Spectrophotometer, DR/4000 |
| Hardness | Titration with 0.01M EDTA, using EBT indicator and ammonia buffer |
| Alkalinity | Titration with N/50 $H_2SO_4$,using bromocresol green indicator |
| Chloride | Argentometric method |
| Sulphate | Turbiditymetric method |
| Sodium | Microprocessor based flame photometer |
| Potassium | Flame photometer |
| Calcium | Titration with 0.01M EDTA, murexide indicator |
| Total Coliform | Multiple tube fermentation technique autoclave |
| TDS | Evaporation at $105^0C$ |
| Phosphate | Spectrophotometer, DR/4000 |
| Ammonical Nitrogen | Spectrophotometer, DR/4000 |
| Nitrate Nitrogen | Spectrophotometer, DR/4000 |
| Heavy Metals | Atomic Absorption Spectrophotometer |

**Table: 6 Physico-chemical analysis of water and wastewater**

| Parameters | Year 2006-2007 | | Year 2007-2008 | WHO[a]/ Pescod[b]/ FAO[c] limits of Water quality for irrigation |
|---|---|---|---|---|
| | Tap Water (range) | Wastewater 38 ML/d (range) | Wastewater 34 ML/d (range) | |
| pH | 7.35-7.52 | 7.24-7.50 | 7.10-7.46 | 6.5-8.4 [c] |
| EC(μmhos/cm at 25 $^0$C) | 608-625 | 827-858 | 1598-1890 | 0.25-3.0 [c] |
| TDS (mg/L) | 360-386 | 400-738 | 955-1234 | <2000 [c] |
| BOD(mg/L) | 0-0 | 20-33 | 32-47 | 100 [b] |
| COD(mg/L) | 0-0 | 49-100 | 110-150 | 250 [b] |
| DO(mg/L) | 4.59-4.84 | 2.4-3.8 | 0-0 | -- |
| Calcium as Ca (mg/L) | 57-61 | 76-78 | 116-119 | < 400 [c] |
| Magnessium as Mg (mg/L)* | 18.5-25.3 | 40.5-45.1 | 60.5-63.0 | < 61 [c] |
| Potassiumas K (mg/L)* | 3.2-3.9 | 13.8-14.6 | 22.2-24.0 | < 2.0 [c] |
| Sodium as Na (mg/L) | 31.1-39.5 | 53.1-60.2 | 330-333 | < 460 [c] |
| Total Hardness as $CaCO_3$(mg/L) | 250-283 | 344-358 | 520-526 | -- |
| Total Alkalinity as $CaCO_3$ (mg/L) | 252-265 | 390-400 | 490-500 | < 610 [c] |
| Chloride as $Cl^-$ (mg/L)* | 14.0-16.5 | 45.8-48.0 | 510-515 | < 350 [c] |
| Sulphate as $SO4^{-2}$ (mg/L) | 15.0-16.2 | 43.3-45.8 | 171-173 | -- |
| Phosphate as $PO_4$-P (mg/L)* | 0-0 | 5.1-5.7 | 5.6-10.4 | < 2.0 [c] |
| Nitrate Nitrogen as $NO_3$-N(mg/L) | 0.026-0.316 | 0.4-3.2 | 0.8-2.3 | < 10.0 [c] |
| Ammonical Nitrogen as $NH_4$-N(mg/L)* | 0 | 27.0-50.0 | 63-75 | < 5.0 [c] |
| Total Coliform (MPN/100mL) | <3 | $20x10^3$-$23x10^4$ | $21x10^4$-$93x10^6$ | -- |
| Feacal Coliform (MPN/100mL)* | <3 | $20x10^3$-$23x10^4$ | $21x10^4$-$93x10^6$ | 1000 [a] |
| Cadmium as Cd (mg/L) | 0-0.005 | 0.006-0.022 | 0-0.009 | 0.01[b] |
| Chromium as Cr (mg/L) | 0-0.001 | 0-0.121 | 0.003-0.031 | 0.1 [b] |
| Nickel as Ni (mg/L) | 0.011-0.016 | 0.012-0.026 | 0.016-0.031 | 0.2 [b] |
| Iron as Fe (mg/L) | 0.019-0.201 | 0.271-0.772 | 0.110-0.212 | < 5.0 [c] |
| Copper as Cu (mg/L) | 0.005-0.009 | 0.022-0.031 | 0.018-0.022 | 0.2 [b] |
| Manganese as Mn (mg/L) | 0.005-0.109 | 0.072-0.148 | 0.051-0.054 | < 0.2 [c] |
| Zinc as Zn (mg/L) | 0.006-0.008 | 0.087-0.115 | 0.105-0.112 | < 2.0 [c] |

*values crossed the limits of WHO[a], (1989), Pescod[b], (1992), and Ayers and Westcot FAO[c], (1994) for irrigation water.

Fig: 9. Hach DR/4000

Fig: 10. COD Digester


Fig: 11. DO Meter

Fig: 12. BOD Incubator

Fig: 13. Digestion Apparatus

Fig: 14. Atomic Absorption Spectrophotometer

Fig 9-14. Showing instruments and equipments used in the experimentation

## 3.6 SOIL ANALYSIS

Samples of soils were collected from the experimental pots prior to each experiment and also before the addition of NPK and analyzed in 2006 and 2007. Soil samples were air dried, ground and passed through 2 mm sieve and analyzed for soil texture, cation exchange capacity, organic carbon, pH, conductivity, total nitrogen, phosphorus, potassium and heavy metals (Cd, Cr, Ni, Fe, Cu, Mn and Zn). Measurements were made in duplicate. Details of analysis procedure are given below. Soil texture was measured by using USDA soil textural triangle after determining the % of sand, silt, and clay by hydrometry and sieve analysis (Arora, 2000). Organic carbon and pH was determined by Behera, (2006) conductivity, and total phosphorus by Bear, (1964). Total kjeldhal nitrogen, Hach manual (1999) while Cd, Cr, Ni, Fe, Cu, Mn and Zn were digested with sulphuric acid procedure followed Hach manual (1999) and measured by means of Atomic Absorption Spectrophotometer (model GBC Avanta M).

### 3.6.1 pH

It was estimated with the help of pH meter. To 20 g soil, 40 ml of distilled water (1:2) was added and shaken thoroughly. After 1 hour, pH of the suspension was recorded. The pH meter was calibrated with a standard of known pH.

### 3.6.2 Conductivity

It was estimated with the help of conductivity meter. 50 g soil sample was taken into a 250 ml Erlenmeyer flask. 100 ml of distilled water was added. After 30 minutes, shakend occasionally. Conductivity of supernatant was recorded with the help of conductivity meter.

### 3.6.3 Cation Exchange Capacity (CEC)

CEC of soil was determined by the method of Ganguly (1951). To 10 g soil, 0.2N HCl (Appendix-1) was added. It was shaken for 30 minutes, filtered and washed with DDW, till it became free from chloride ions, which was checked with $AgNO_3$. The residue was transferred from the filter paper to a beaker and suspension of known concentration was prepared. It was then treated with 10 ml of standard KCl solution (Appendix-1), shaken for 30 minutes and left overnight. Then it was titrated with 0.1N NaOH (Appendix-1), using phenolphthalein indicator. From the amount of NaOH required, the CEC of samples was calculated as follows.

$$CEC\,(meq\,100g^{-1}) = \frac{Volume\ of\ 0.1\,N\ NaOH \times N\ of\ NaOH}{Weight\ of\ sample}$$

### 3.6.4 Organic Carbon

It was estimated by the method of Walkley and Black (1934). 0.25 g sample was taken in a 500 ml conical flask. To this 10 ml of 1N potassium dichromate solution (Appendix-1), and 20 ml concentrated sulphuric acid were added. After shaking allow the mixture was allowed to stand for 30 minutes. Later 200 ml DDW, 10 ml phosphoric acid (85%) and 1 ml of diphenyl amine indicator (Appendix-1) were added. Deep violet colour appeared which was titrated with 1N ferrous ammonium sulphate (Appendix-1), solution till the colour changed to purple and finally green. Simultaneously a blank was run without sample.

$$\%\,of\ Organic\ Carbon = \frac{Blank\ titrant - Actual\ titrant}{Weight\ of\ sample} \times 0.003 \times 100 \times N$$

Where N= normality of ferrous ammonium sulphate.

### 3.6.6 Total Kjeldhal Nitrogen (TKN)

0.5 g soil sample was taken into a 100 mL digesdahl digestion flask. 4 mL concentrated sulphuric acid was added to the digestion flask and it was kept on the heater and allowed to boil at a temperature of $440^0$ C for 4 minutes. After that 10-20 mL of 30% hydrogen per oxide was added to the flask until it became colorless. Then the flask along with its contents was allowed to cool and the final volume was made up to 100 mL. 3 ml of digested sample was taken for TKN analysis. Analysis was carried out as Hach manual (1999).

### 3.6.7 Total Phosphorus

Digestion procedure was similar as 3.6.6. After digestion 1mL sample was taken in 100 mL nesselers tube and diluted up to 100 mL with distillled water. 4 mL ammonium molybdate solution (Appendix-1), and 0.5 mL of stannous chloride

(Appendix-1), was added and mixed well. It was left for 10 minutes and recorded the absorbance at 690 nm.

### 3.6.8 Total Potassium

Digestion procedure was similar as 3.6.6. Reading was taken with the help of flame photometer. The curve was obtained by plotting the readings against the different concentrations ranging from 10, 20, 30, 40 and 50 ppm of K.

### 3.6.9 Heavy Metals

Digestion procedure was similar as 3.6.6. Digested samples were analyzed using Atomic Absorption Spectrophotometer. Standard solutions of heavy metals and potassium (1000 mg/L) were procured from Merck Solutions and varying concentrations were prepared for all the metals during the standards.

**Table: 7 Physico-chemical analysis of soil characteristics**

| Parameters | 2006-2007 (range) Experiment I, II | 2007-2008 (range) Experiment III, IV | Excessive levels of heavy metal in soil Linzon, (1978) |
|---|---|---|---|
| Soil Texture | Sandy loam | Sandy loam | -- |
| Sand (%) | 60.0 | 69.0 | -- |
| Silt (%) | 33.0 | 23.0 | -- |
| Clay (%) | 7.0 | 8.0 | -- |
| CEC (meq 100 $g^{-1}$ soil) | 3.08-3.76 | 3.30-3.58 | -- |
| pH | 7.92-8.09 | 8.05-8.11 | -- |
| Organic carbon (%) | 0.72-0.95 | 0.78-0.85 | -- |
| EC (µmhos/cm) | 283-320 | 290-310 | -- |
| Total Nitrogen (mg/kg) | 156-224 | 145-220 | -- |
| Total Phosphorus (mg/kg) | 200-235 | 205-245 | -- |
| Total Potassium (mg/kg) | 50-60 | 70-80 | -- |
| Cadmium (mg/kg)* | 8-15 | 12-14 | 8.0 |
| Chromium (mg/kg) | 35-36 | 35-38 | 75 |
| Nickel (mg/kg)* | 78-159 | 118-162 | 100 |
| Iron (mg/kg) | 13100-16000 | 14400-15800 | -- |
| Copper (mg/kg) | 18-21 | 18-27 | 100 |
| Manganese (mg/kg) | 310-340 | 300-350 | 1500 |
| Zinc (mg/kg) | 72-184 | 147-195 | 400 |

*values crossed the limits of Linzon, 1978 for soil.

## 3.7 PLANT ANALYSIS

Soil in pots containing single plant of turnip was treated with 32 different types of water (Table 1-4). Three replicates of plant samples from each treatment were collected and gently washed with running tap water to remove soil particles attached to the plant surfaces and finally rinsed with deionised water. Subsequently plant measurements were made (Table 8). Afterwards leaves and roots were separated and oven dried at $70^0C$ to a constant weight. The dried tissues were weighed and ground into powder for metal analysis. Dried samples were digested as per the procedure given in Hach manual (1999). Metal analysis of the plant samples was carried out by Atomic Absorption Spectrophotometer (Model GBC Avanta M).

### *3.7.1 Growth characteristics*

The following growth characteristics were observed using standard practices.

**Table: 8 Growth characteristics of plant**

| S. No. | Parameters | S. No. | Parameters |
|---|---|---|---|
| 1. | Leaf number/plant | 6. | Root fresh weight/plant (g) |
| 2. | Root diameter/plant (cm) | 7. | Root dry weight/plant (g) |
| 3. | Plant height/plant (cm) | 8. | Leaf fresh weight/plant (g) |
| 4. | Fresh weight /plant (g) | 9. | Leaf dry weight/plant (g) |
| 5. | Dry weight/plant (g) | | |

## 3.8 STATISTICAL ANALYSIS

The data obtained were analyzed statistically taking into consideration the variables in each experiment according to Panse and Sukhatme (1985). The "F" test was applied to assess the significance of data at 5% level of probability ($P \leq 0.05$). The error due to replication was also determined. The model of analysis of variance (ANOVA) is given in tables 9, 10, 11, and 12 Critical difference (CD) was also calculated to compare the mean value of various treatments. Correlation coefficient values ($r^2$) and regression analysis ($R^2$) were obtained with some growth and yield attributing parameters (Fig. 12, 13,14a-c).

**Table: 9 Model of analysis of variance (ANOVA) of Experiment-I**

| Source of variation | df | SS | MSS | F. value | Sig. |
|---|---|---|---|---|---|
| Replication | 2 | | | | |
| Treatment | 7 | | | | |
| Error | 14 | | | | |

**Table: 10 Model of analysis of variance (ANOVA) of Experiment-II**

| Source of variation | df | SS | MSS | F. value | Sig. |
|---|---|---|---|---|---|
| Replication | 2 | | | | |
| Treatment | 7 | | | | |
| Error | 14 | | | | |

**Table: 11 Model of analysis of variance (ANOVA) of Experiment-III**

| Source of variation | df | SS | MSS | F. value | Sig. |
|---|---|---|---|---|---|
| Replication | 2 | | | | |
| Water/wastewater | 1 | | | | |
| Phosphorus (P) | 3 | | | | |
| Interaction | 3 | | | | |
| Error | 14 | | | | |
| Total | 23 | | | | |

**Table: 12 Model of analysis of variance (ANOVA) of Experiment-IV**

| Source of variation | df | SS | MSS | F. value | Sig. |
|---|---|---|---|---|---|
| Replication | 2 | | | | |
| Water/wastewater | 1 | | | | |
| Potassium (K) | 3 | | | | |
| Interaction | 3 | | | | |
| Error | 14 | | | | |
| Total | 23 | | | | |

CHAPTER 4

# EXPERIMENTAL RESULTS

## 4.1 EXPERIMENT- I

### 4.1.1 *Growth and yield characteristics*

**4.1.1.1 Plant Fresh Weight**: At 40 days, wastewater proved beneficial as it recorded equal fresh weight of the crop grown with tap water (TW) supplemented with 25 kg P/ha ($TWP_{25}$) showing the utility of wastewater as a source of irrigation water as well as plant nutrients specially the P in the present study. It may be noted that 100% wastewater (100%ww) was best among different concentrations and $TWP_{25}$ was optimum among P treatments while $TWP_{50}$ proved excessive (Table 13). More or less similar trend was observed at later two stages where 100% wastewater gave statistically different values and $TWP_{25}$ closely followed the former. The percent increase in fresh weight with 100% wastewater over TW alone was 149.86, 122.43 and 147.46 at 40, 55 and 70 DAS respectively while % increase in $TWP_{25}$ over TW was 138.25, 46.96, and 107.08%. As generally observed in other crops, turnip plant fresh weight was increased up to the last sampling stage.

**4.1.1.2 Plant Dry Weight:** Except at 40 DAS, where $TWP_{25}$ proved best, at later two stages, like plant fresh weight, 100% wastewater without fertilizer (100%ww) proved better than $TWP_{25}$. Similarly, 100%ww was better among four concentrations of wastewater while $TWP_{25}$ was better among the phosphorus treatments applied with tap water (Table 13). Percent increase in optimum wastewater treatment was 58.33, 86.74 and 180.46 over TW alone at three stages of sampling while % increase in $TWP_{25}$ over TW alone was 136.90, 26.81 and 68.42. Like fresh weight, dry weight also increased up to the last stage of sampling.

**4.1.1.3 Plant Height:** This parameter was more affected with phosphorus doses in comparison to wastewater as the three doses $P_{12.5}$, $P_{25}$ and $P_{50}$ were better than the wastewater and tap water treatments at all the three stages of growth (Table 13). It may also be noted that among the three phosphorus doses, $P_{12.5}$ was comparatively better while in case of wastewater treatments 100%ww proved more beneficial. In general plant height also enhanced with growth.

**4.1.1.4 Root Fresh Weight:** It was significantly enhanced with 100%ww at three samplings and gave more root fresh weight than obtained under any dose of P given with TW (Table 14). Among the phosphorus treatments although $TWP_{25}$ proved best at the harvest stage (70 DAS) $TWP_{50}$ proved better at earlier (40, 55 DAS) two samplings where it gave 14.06 and 7.81 more root fresh weight than TW alone. Root fresh weight was also increased with the increase in growth up to the last sampling.

**4.1.1.5 Root Dry Weight:** 100%ww proved better over other concentrations including TW at all the stages studied (Table 14). Similarly 50%ww gave 5.0, 7.37, and 356.15% more dry weight than TW. Like root fresh weight, $P_{25}$ and $P_{50}$ recorded better values over $P_{12.5}$ as the former treatment was better at harvest while the latter treatment proved effective at earlier two stages. Like root fresh weight, root dry weight also enhanced up to last stage.

**4.1.1.6 Root Diameter:** Significant increase in root growth was observed with wastewater as well as with phosphatic fertilizer (Table 14). Thus 100% wastewater recorded maximum root diameter at all the three stages of growth giving 130.0, 300.0, and 382.89 more values than TW alone. It may be of interest to note that this treatment recorded more growth when compared with $TWP_{25}$ showing the utility of waste water. Even 50%ww recorded 10, 15.87, and 119.74 more diameter of root than TW alone which is supposed to be the optimum treatment at 55 and 70 DAS, and also in most of the other parameters observed in the present study. Similarly $TWP_{25}$ gave 163.16 more root diameter than $TWP_0$ at 70 DAS. Diameter of root was increased after each sampling.

**4.1.1.7 Leaf Fresh Weight:** Contrary to earlier observations, 50%ww proved better than 100%ww at all the three samplings while TW was poorest among all water treatments (Table 15). The increase by 50%ww over 100%ww was 16.98, 28.48, and 14.42%. In case of P treatments again $P_{25}$ proved better when given with TW recording an increase of 154.16, 60.57 and 73.77 more leaf fresh weight over TW alone.

**Table: 13 Effect of TW, with four levels of phosphorus and four concentrations of WW on plant fresh weight (g plant$^{-1}$), plant dry weight (g plant$^{-1}$) and plant height (cm plant$^{-1}$) of turnip (*Brassica rapa*) at three stages of sampling.**

| Treatments | Plant Fresh Weight | | | Plant Dry Weight | | | Plant Height | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | 55 | 70 | 40 | 55 | 70 | 40 | 55 | 70 |
| TW+$N_0P_0K_0$ | 6.98 | 11.50 | 15.95 | 0.84 | 1.38 | 1.52 | 19.2 | 20.0 | 22.0 |
| TW+$N_{50}P_{12.5}K_{25}$ | 10.98 | 14.00 | 24.09 | 1.15 | 1.44 | 1.85 | 32.5 | 33.8 | 43.0 |
| TW+$N_{50}P_{25}K_{25}$ | 16.63 | 16.90 | 33.03 | 1.99 | 1.75 | 2.56 | 33.8 | 39.0 | 40.5 |
| TW+$N_{50}P_{50}K_{25}$ | 10.40 | 15.74 | 29.48 | 1.06 | 1.60 | 2.27 | 30.5 | 36.8 | 37.0 |
| 25%WW | 15.93 | 16.55 | 17.58 | 1.43 | 1.72 | 1.40 | 24.2 | 19.0 | 22.4 |
| 50%WW | 17.38 | 18.00 | 22.88 | 1.63 | 1.85 | 2.24 | 22.3 | 21.1 | 25.6 |
| 75%WW | 10.25 | 16.81 | 31.68 | 0.95 | 1.31 | 3.33 | 23.5 | 27.0 | 29.2 |
| 100%WW | 17.44 | 25.58 | 39.47 | 1.33 | 2.58 | 4.26 | 22.5 | 28.3 | 28.9 |
| **C.D. at 5%** | **1.074** | **1.343** | **2.208** | **0.107** | **0.136** | **0.202** | **1.861** | **1.942** | **2.066** |

**Table: 14 Effect of TW, with four levels of phosphorus and four concentrations of WW on root fresh weight (g plant$^{-1}$), root dry weight (g plant$^{-1}$) and root diameter (cm) of turnip (*Brassica rapa*) at three stages of sampling.**

| Treatments | Root Fresh Weight | | | Root Dry Weight | | | Root Diameter | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | 55 | 70 | 40 | 55 | 70 | 40 | 55 | 70 |
| TW+$N_0P_0K_0$ | 0.64 | 1.28 | 1.54 | 0.060 | 0.109 | 0.130 | 0.50 | 0.63 | 0.76 |
| TW+$N_{50}P_{12.5}K_{25}$ | 0.73 | 0.93 | 1.98 | 0.080 | 0.090 | 0.160 | 0.80 | 0.35 | 1.20 |
| TW+$N_{50}P_{25}K_{25}$ | 0.47 | 0.49 | 7.99 | 0.050 | 0.060 | 0.550 | 0.40 | 0.55 | 2.00 |
| TW+$N_{50}P_{50}K_{25}$ | 0.73 | 1.38 | 3.73 | 0.090 | 0.130 | 0.280 | 0.67 | 0.35 | 1.70 |
| 25%WW | 0.56 | 1.35 | 5.97 | 0.060 | 0.107 | 0.570 | 0.52 | 0.79 | 1.85 |
| 50%WW | 0.71 | 1.13 | 5.98 | 0.063 | 0.117 | 0.593 | 0.55 | 0.73 | 1.67 |
| 75%WW | 1.29 | 6.34 | 11.8 | 0.117 | 0.670 | 0.900 | 0.70 | 0.95 | 2.40 |
| 100%WW | 3.19 | 12.5 | 24.7 | 0.340 | 1.043 | 2.047 | 1.15 | 2.52 | 3.67 |
| **C.D. at 5%** | **0.105** | **0.394** | **0.810** | **0.011** | **0.035** | **0.066** | **0.056** | **0.082** | **0.158** |

N.B: Subscript values denote the amount of (NPK) in kg ha$^{-1}$. C.D: Critical Difference, DAS: Days After Sowing, WW: Wastewater, TW: Tap Water

**4.1.1.8 Leaf Dry Weight:** In this parameter also, 50%ww was better than other water treatments at first two stages while at last stage unexpectedly 75%ww proved more effective than other treatments (Table 15). While in case of P treatments $TWP_{25}$ was best recording an increase of 148.72, 32.97 and 44.60% more weight than TW proving the importance of inorganic fertilizers. Leaf dry weight increased up to the last stage of growth studied.

**4.1.1.9 Leaf Number:** Leaf production although significantly affected with wastewater as well as phosphorus but the crop responded differently at the three stages (Table 15). Mention may be made of 40 DAS, stage where $TW_{12.5}$ was better than 100%ww alone which may again be benefited by wastewater use as it proved good at 55 DAS, recording an increase of 33.33% more leaf number over TW. Similarly, like first sampling, at last sampling also tap water with higher dose of phosphorus ($TWP_{50}$) proved good which was closely followed by 100%ww which gave just 9.57% lower leaf production. Leaf number was not much affected with advancement of age.

### 4.1.2 *Heavy metal content in root and leaf of turnip*

**4.1.2.1 Cadmium:** It was comparatively more in roots than in leaves at all the stages. In case of leaf Cd was increased with increased P doses at later two stages (Table 16). While among the wastewater concentrations it was generally decreased with increased concentration. Its concentration decreased with increase in growth in most of the treatments. TW also added Cd concentration in roots in addition to other treatments of waste water and phosphorus. Higher concentration of Cd was present in wastewater when compared to TW. Cd concentration increased with P dose also indicating its presence in inorganic fertilizers. Its concentration in root generally decreased with increasing concentration of wastewater.

**4.1.2.2 Chromium:** In root it was not found in tap water at all the three stages of samplings while it was present in treatments of wastewater (Table 17). It may also be noted that this element was not detected in the treatments of phosphatic fertilizers although it may be present as an impurity in fertilizers. Significantly Cr was not detected in leaf. Cr was also decreased with increased concentration of wastewater as

**Table: 15 Effect of TW, with four levels of phosphorus and four concentrations of WW on leaf fresh weight (g plant$^{-1}$), leaf dry weight (g plant$^{-1}$) and leaf number (plant$^{-1}$) of turnip (*Brassica rapa*) at three stages of sampling.**

| Treatments | Leaf Fresh Weight | | | Leaf Dry Weight | | | Leaf Number | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | 55 | 70 | 40 | 55 | 70 | 40 | 55 | 70 |
| $TW+N_0P_0K_0$ | 6.34 | 10.22 | 14.41 | 0.78 | 1.27 | 1.39 | 5.00 | 6.00 | 7.00 |
| $TW+N_{50}P_{12.5}K_{25}$ | 10.25 | 13.07 | 22.11 | 1.07 | 1.35 | 1.69 | 8.67 | 7.00 | 6.33 |
| $TW+N_{50}P_{25}K_{25}$ | 16.16 | 16.41 | 25.04 | 1.94 | 1.69 | 2.01 | 7.33 | 6.33 | 6.33 |
| $TW+N_{50}P_{50}K_{25}$ | 9.67 | 14.36 | 25.75 | 0.97 | 1.47 | 1.99 | 7.33 | 7.33 | 7.67 |
| 25%WW | 15.37 | 15.20 | 11.61 | 1.37 | 1.61 | 0.83 | 6.00 | 4.67 | 6.00 |
| 50%WW | 16.67 | 16.87 | 16.90 | 1.57 | 1.74 | 1.65 | 5.67 | 6.67 | 7.00 |
| 75%WW | 8.96 | 10.47 | 19.84 | 0.83 | 0.64 | 2.43 | 5.67 | 5.33 | 6.67 |
| 100%WW | 14.25 | 13.13 | 14.77 | 0.99 | 1.53 | 2.22 | 7.67 | 8.00 | 7.00 |
| **C.D. at 5%** | **0.997** | **1.111** | **1.609** | **0.100** | **0.116** | **0.148** | **0.556** | **0.524** | **0.535** |

N.B: Subscript values denote the amount of (NPK) in kg ha$^{-1}$. C.D: Critical Difference, DAS: Days After Sowing, WW: Wastewater, TW: Tap Water well as with age of the plant. While in case of leaf Cr was not found in tap water as well as in wastewater at all the three stages of sampling.

**4.1.2.3 Nickel:** In root, it was present in tap water as well as in wastewater treatments (Table 18). Its Concentration increased in wastewater with increasing concentration of wastewater. Ni concentration differed stage wise and treatment wise i.e., at 40 DAS, it was maximum in $TWP_{50}$, while at 55 DAS, $TW_{12.5}$ was more effective and at the last sampling it was more in $TWP_{25}$. Compared to root Ni concentration was generally more in leaf. Its concentration was also high in wastewater treatments as compared to tap water. In leaf, its concentration increased generally with increasing concentration of wastewater and concentration differed stage wise and treatment wise i.e. at 40 days it was maximum in $TWP_{50}$ while at 55 days $TWP_{12.5}$ accumulated more Ni and at the last sampling it was again more in $TWP_{25}$. Ni was generally decreased with increase in growth.

**4.1.2.4 Iron:** It was found in tap water as well as in wastewater. Concentration of Fe was independent of water concentration (Table 19). It was also increased with increase of P up to $TWP_{25}$ at later two stages while at early stage it enhanced up to $TWP_{50}$. It was more in root than leaf in wastewater treatments. Fe Concentration was more than Cd, Cr, Ni, Mn, Cu and Zn. In leaves its concentration was more in TW at all the stages of sampling in comparison to WW and among the P doses generally $TWP_{50}$ recorded maximum Fe content. Its concentration increased up to $TWP_{50}$ at 40 days while at 55 and 70 days it was found to be maximum in $TWP_{25}$ in root. Its concentration generally decreased with growth of plant.

**4.1.2.5 Copper:** In case of root like Cr, Cu is also absent in tap water alone and tap water with P doses (Table 20). Its concentration was also independent of wastewater concentration. In upper part of the plant Cu is absent in tap water as well as in tap water with different P doses. Like root, Cu concentration was also independent of wastewater concentration in leaf.

**Table: 16 Effect of TW with four levels of phosphorus and different concentrations of WW on cadmium (mg/kgDW) content in root and leaf of turnip (*Brassica rapa*) at three stages of sampling.**

| Treatments | Cadmium in root | | | Cadmium in leaf | | |
|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | |
| | 40 | 55 | 70 | 40 | 55 | 70 |
| TW+$N_0P_0K_0$ | 1.95 | 2.50 | 0.50 | 1.25 | 2.25 | 0.53 |
| TW+$N_{50}P_{12.5}K_{25}$ | 3.85 | 3.25 | 0.75 | 3.75 | 3.00 | 1.00 |
| TW+$N_{50}P_{25}K_{25}$ | 3.10 | 3.50 | 0.88 | 3.00 | 3.25 | 1.00 |
| TW+$N_{50}P_{50}K_{25}$ | 1.15 | 4.35 | 2.15 | 1.25 | 4.25 | 2.25 |
| 25%WW | 20.0 | 12.5 | 6.00 | 2.25 | 7.75 | 4.00 |
| 50%WW | 25.0 | 8.45 | 5.00 | 6.25 | 3.00 | 4.50 |
| 75%WW | 13.0 | 6.75 | 6.50 | 7.75 | 2.50 | 3.50 |
| 100%WW | 5.50 | 6.00 | 7.75 | 4.00 | 2.25 | 3.50 |
| **C.D. at 5%** | **1.432** | **0.609** | **0.388** | **0.374** | **0.324** | **0.239** |

**Table: 17 Effect of TW with four levels of phosphorus and different concentrations of WW on chromium (mg/kg DW) content in root and leaf of turnip (*Brassica rapa*) at three stages of sampling.**

| Treatments | Chromium in root | | | Chromium in leaf | | |
|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | |
| | 40 | 55 | 70 | 40 | 55 | 70 |
| TW+$N_0P_0K_0$ | N.D. | N.D. | ·N.D. | N.D. | N.D. | N.D. |
| TW+$N_{50}P_{12.5}K_{25}$ | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. |
| TW+$N_{50}P_{25}K_{25}$ | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. |
| TW+$N_{50}P_{50}K_{25}$ | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. |
| 25%WW | 37.50 | 30.95 | 26.0 | N.D. | N.D. | N.D. |
| 50%WW | 46.00 | 11.60 | 9.00 | N.D. | N.D. | N.D. |
| 75%WW | 32.50 | 10.50 | 5.00 | N.D. | N.D. | N.D. |
| 100%WW | 17.50 | 7.00 | N.D. | N.D. | N.D. | N.D. |
| **C.D. at 5%** | **2.029** | **1.016** | **0.840** | **NS** | **NS** | **NS** |

N.B: Subscript values denote the amount of phosphorus (NPK) in kg $ha^{-1}$. C.D: Critical Difference, DW: Dry Weight, N.S: Non Significant, N.D: Not Detectable, DAS: Days After Sowing, WW: Wastewater, TW: Tap Water

**Table: 18 Effect of TW with four levels of phosphorus and different concentrations of WW on nickel (mg/kg DW) content in root and leaf of turnip (*Brassica rapa*) at three stages of sampling.**

| Treatments | Nickel in root | | | Nickel in leaf | | |
|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | |
| | 40 | 55 | 70 | 40 | 55 | 70 |
| TW+$N_0P_0K_0$ | 68.0 | 15.0 | 24.0 | 61.0 | 32.0 | 12.0 |
| TW+$N_{50}P_{12.5}K_{25}$ | 90.0 | 15.0 | 30.0 | 83.0 | 36.0 | 16.0 |
| TW+$N_{50}P_{25}K_{25}$ | 88.0 | 12.0 | 76.0 | 80.0 | 33.0 | 66.0 |
| TW+$N_{50}P_{50}K_{25}$ | 95.6 | 10.0 | 56.4 | 91.0 | 25.0 | 46.0 |
| 25%WW | 99.0 | 21.0 | 30.0 | 23.0 | 91.0 | 93.0 |
| 50%WW | 60.0 | 40.0 | 72.0 | 108.0 | 102.0 | 107.0 |
| 75%WW | 62.0 | 42.0 | 57.0 | 110.0 | 108.0 | 98.0 |
| 100%WW | 68.0 | 47.0 | 52.0 | 106.0 | 69.0 | 105.0 |
| **C.D. at 5%** | **6.80** | **2.365** | **4.406** | **7.484** | **5.702** | **5.973** |

**Table:19 Effect of TW with four levels of phosphorus and different concentrations of WW on iron (mg/kg DW) content in root and leaf of turnip (*Brassica rapa*) at three stages of sampling.**

| Treatments | Iron in root | | | Iron in leaf | | |
|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | |
| | 40 | 55 | 70 | 40 | 55 | 70 |
| TW+$N_0P_0K_0$ | 770 | 695 | 668 | 870 | 795 | 778 |
| TW+$N_{50}P_{12.5}K_{25}$ | 871 | 745 | 769 | 938 | 946 | 893 |
| TW+$N_{50}P_{25}K_{25}$ | 989 | 885 | 867 | 1103 | 740 | 558 |
| TW+$N_{50}P_{50}K_{25}$ | 1162 | 746 | 565 | 1255 | 1087 | 891 |
| 25%WW | 1672 | 1765 | 949 | 648 | 692 | 647 |
| 50%WW | 1779 | 1770 | 832 | 602 | 607 | 503 |
| 75%WW | 1835 | 1172 | 1080 | 1247 | 754 | 482 |
| 100%WW | 1753 | 1165 | 935 | 989 | 1073 | 522 |
| **C.D. at 5%** | **113.5** | **96.2** | **70.13** | **82.19** | **71.60** | **58.56** |

N.B: Subscript values denote the amount of phosphorus (NPK) in kg $ha^{-1}$. C.D: Critical Difference, DW: Dry Weight, DAS: Days After Sowing, WW: Wastewater, TW: Tap Water

**4.1.2.6 Manganese:** It was present in tap water as well as in wastewater in underground part of the plant (Table 21). Mn concentration in general increased with increased P doses, while in wastewater its concentration was decreased with increase in concentration. Like Cu its concentration was more or less similar in both organs. In case of leaf its concentration in general increased with increased in P doses and it was independent of wastewater concentrations. It was decreased with growth among the wastewater concentrations in root.

**4.1.2.7 Zinc:** Like Mn, in root Zn was also present in tap water as well as in wastewater (Table 22). It was also decreased with increase in wastewater concentrations. Not much difference was observed between the root and leaf in TW treatments. In leaf tissues wastewater contained more Zn than the tap water. In leaf among the P doses at 40 days Zn was maximum in $TWP_{12.5}$ and at 55 and 70 DAS, it was maximum in $TWP_{50}$. Its concentration in general decreased with growth.

**Table: 20 Effect of TW with four levels of phosphorus and different concentrations of WW on copper (mg/kg DW) content in root and leaf of turnip (*Brassica rapa*) at three stages of sampling.**

| Treatments | Copper in root | | | Copper in leaf | | |
|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | |
| | 40 | 55 | 70 | 40 | 55 | 70 |
| TW+$N_0P_0K_0$ | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. |
| TW+$N_{50}P_{12.5}K_{25}$ | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. |
| TW+$N_{50}P_{25}K_{25}$ | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. |
| TW+$N_{50}P_{50}K_{25}$ | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. |
| 25%WW | 19.0 | 4.50 | 3.00 | 5.50 | 26.5 | 3.50 |
| 50%WW | 21.5 | 3.00 | 3.50 | 7.50 | 20.5 | 3.50 |
| 75%WW | 1.50 | 6.00 | 6.00 | 6.50 | 20.0 | 6.00 |
| 100%WW | 2.50 | 10.0 | 5.00 | 5.50 | 26.0 | 3.50 |
| **C.D. at 5%** | **0.850** | **0.325** | **0.232** | **0.360** | **1.298** | **0.245** |

**Table: 21 Effect of TW with four levels of phosphorus and different concentrations of WW on manganese (mg/kg DW) content in root and leaf of turnip (*Brassica rapa*) at three stages of sampling.**

| Treatments | Manganese in root | | | Manganese in leaf | | |
|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | |
| | 40 | 55 | 70 | 40 | 55 | 70 |
| TW+$N_0P_0K_0$ | 102.0 | 72.0 | 95.0 | 112.4 | 74.8 | 99.0 |
| TW+$N_{50}P_{12.5}K_{25}$ | 127.6 | 98.0 | 130.6 | 137.6 | 113.8 | 137.6 |
| TW+$N_{50}P_{25}K_{25}$ | 152.0 | 96.0 | 109.0 | 162.0 | 112.4 | 111.5 |
| TW+$N_{50}P_{50}K_{25}$ | 163.0 | 129.0 | 149.0 | 160.2 | 139.8 | 139.0 |
| 25%WW | 231.0 | 209.0 | 200.0 | 212.0 | 101.0 | 105.0 |
| 50%WW | 233.0 | 208.0 | 99.0 | 136.0 | 81.0 | 105.0 |
| 75%WW | 158.0 | 127.0 | 101.0 | 175.0 | 87.0 | 111.0 |
| 100%WW | 135.0 | 82.0 | 83.0 | 174.0 | 112.0 | 128.0 |
| **C.D. at 5%** | **13.86** | **11.37** | **10.59** | **13.14** | **8.85** | **10.02** |

N.B: Subscript values denote the amount of phosphorus (NPK) in kg $ha^{-1}$. C.D: Critical Difference, DW: Dry Weight, N.D: Not Detectable, DAS: Days After Sowing, WW: Wastewater, TW: Tap Water

**Table: 22 Effect of TW with four levels of phosphorus and different concentrations of WW on zinc (mg/kg DW) content in root and leaf of turnip (*Brassica rapa*) at three stages of sampling.**

| Treatments | Zinc in root | | | Zinc in leaf | | |
|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | |
| | 40 | 55 | 70 | 40 | 55 | 70 |
| $TW+N_0P_0K_0$ | 83.0 | 40.0 | 80.0 | 81.6 | 46.0 | 75.6 |
| $TW+N_{50}P_{12.5}K_{25}$ | 102.0 | 42.0 | 46.0 | 97.6 | 48.0 | 43.0 |
| $TW+N_{50}P_{25}K_{25}$ | 111.0 | 61.0 | 62.0 | 91.2 | 59.6 | 57.7 |
| $TW+N_{50}P_{50}K_{25}$ | 98.0 | 95.0 | 70.0 | 95.4 | 92.0 | 72.8 |
| 25%WW | 214.0 | 216.0 | 191.0 | 92.0 | 128.0 | 97.0 |
| 50%WW | 208.0 | 201.0 | 160.0 | 96.0 | 78.0 | 95.0 |
| 75%WW | 149.0 | 144.0 | 116.0 | 105.0 | 81.0 | 86.0 |
| 100%WW | 93.0 | 107.0 | 92.0 | 102.0 | 94.0 | 102.0 |
| **C.D. at 5%** | **11.66** | **10.33** | **8.89** | **7.98** | **6.47** | **6.33** |

N.B: Subscript values denote the amount of phosphorus (NPK) in kg $ha^{-1}$.C.D: Critical Difference, DW: Dry Weight, DAS: Days After Sowing, WW: Wastewater, TW: Tap Water

## 4.2 EXPERIMENT-II

### 4.2.1 *Growth and yield characteristics*

**4.2.1.1 Plant Fresh Weight**: At 40 DAS, $TWK_{25}N_{50}P_{25}$ was optimum followed by $100\%wwN_{100}P_{100}K_{100}$ which was at par with $TWK_{50}N_{50}P_{25}$ (Table 23). The optimum treatment recorded 150.51% increase over TW alone. The treatment, $75\%wwN_{50}P_{50}K_{50}$ was at par with $25\%wwN_{12.5}P_{12.5}K_{12.5}$ which was followed by $50\%wwN_{25}P_{25}K_{25}$ and $TWK_{12.5}N_{50}P_{25}$. On the contrary at 55 DAS, the trend differed where $100\%wwN_{100}P_{100}K_{100}$ proved the best treatment which was closely followed by $50\%wwN_{25}P_{25}K_{25}$ and $75\%wwN_{50}P_{50}K_{50}$ and the latter two treatments were equally effective. At this stage, the best treatment gave 178.61% more plant fresh weight than TW alone. Among the remaining treatments $25\%wwN_{12.5}P_{12.5}K_{12.5}$ and $TWK_{12.5}N_{50}P_{50}$ were also at par on the one hand and on the other the later treatment was equaled by $TWK_{50}N_{50}P_{25}$. At the harvest stage (70 DAS), $50\%wwN_{25}P_{25}K_{25}$ proved optimum as it was at par with $75\%wwN_{50}P_{50}K_{50}$. These two treatments were followed by $25\%wwN_{12.5}P_{12.5}K_{12.5}$ and $100\%wwN_{100}P_{100}K_{100}$ which were also statistically equal with each other. Therefore for this growth parameter $50\%wwN_{25}P_{25}K_{25}$ may be taken up as optimum combination. It may be of interest to note that $TWK_{25}N_{50}P_{25}$ (40 DAS) and $50\%wwN_{25}P_{25}K_{25}$ (70 DAS) were optimum indicating the use of 50%ww may save 25kgN/ha for getting the maximum fresh yield of turnip for commercial marketing. Plant fresh weight increased up to the last sampling stage as noted in earlier experiment also.

**4.2.1.2 Plant Dry Weight:** At 40 DAS, like plant fresh weight, $TWK_{25}N_{50}P_{25}$ proved optimum followed by $100\%wwN_{100}P_{100}K_{100}$ and $25\%wwN_{12.5}P_{12.5}K_{12.5}$ and this treatment was equal to $75\%wwN_{50}P_{50}K_{50}$, and $TWK_{50}N_{50}P_{25}$. $50\%wwN_{25}P_{25}K_{25}$ was also statistically at par with $TWK_{12.5}N_{50}P_{25}$ (Table 23). The optimum treatment recorded 142.42% increase over tap water alone while $100\%wwN_{100}P_{100}K_{100}$ recorded comparatively lesser (116.67%) increase over tap water showing the adverse effect of higher NPK dose. While at 55 DAS, like fresh weight, $100\%wwN_{100}P_{100}K_{100}$ proved the best treatment which was closely followed by $75\%wwN_{50}P_{50}K_{50}$, $50\%wwN_{25}P_{25}K_{25}$ and $25\%wwN_{12.5}P_{12.5}K_{12.5}$ and the last treatment was at par with $TWK_{25}N_{50}P_{25}$. Similarly $TWK_{12.5}N_{50}P_{25}$ was at par with $TWK_{50}N_{50}P_{25}$ recording the lowest value. At the harvest stage, again $50\%wwN_{25}P_{25}K_{25}$ proved optimum as this treatment was at par with 75%ww$N_{50}P_{50}K_{50}$ while 25%ww$N_{12.5}P_{12.5}K_{12.5}$ was at par with100%ww$N_{100}P_{100}K_{100}$ and followed the former treatments. TW$K_{12.5}N_{50}P_{25}$ and TW$K_{25}N_{50}P_{25}$ were equally effective recording the lowest values among all fertilizer treatments. Like plant fresh weight, plant dry weight was also found maximum in 50%ww$N_{25}P_{25}K_{25}$ at the harvest stage thus proving the most economical combination. This parameter was increased up to the last stage of sampling.

**4.2.1.3 Plant Height:** Highest plant length was recorded under TW$K_{12.5}N_{50}P_{25}$ at 40 DAS, and it was at par with 100%ww$N_{100}P_{100}K_{100}$ showing an increase of 42.86% over TW alone (Table 23). 100%ww$N_{100}P_{100}K_{100}$ was at par with TW$K_{50}N_{50}P_{25}$ and TW$K_{25}N_{50}P_{25}$ and 75%ww$N_{50}P_{50}K_{50}$ followed the above treatments which were equaled by 50%ww$N_{25}P_{25}K_{25}$. At 55 DAS, TW$K_{25}N_{50}P_{25}$, showed the maximum plant height among all the treatments although it was at par with 100%ww$N_{100}P_{100}K_{100}$, 50%ww$N_{25}P_{25}K_{25}$ and 75%ww$N_{50}P_{50}K_{50}$ proved equally effective proving that the three waters were not different in case of the plant height. Similarly, TW$K_{50}N_{50}P_{25}$, TW$K_{12.5}N_{50}P_{25}$ and TW alone (TW$K_0N_0P_0$) were at par. At 70 DAS, also almost similar trend was observed where 75%ww$N_{50}P_{50}K_{50}$, showed the maximum plant height and was statistically equal with 50%ww$N_{25}P_{25}K_{25}$, 100%ww$N_{100}P_{100}K_{100}$, TW$K_{50}N_{50}P_{25}$ and 25%ww$N_{12.5}P_{12.5}K_{12.5}$. TW alone gave the lowest value. Plant height increased up to the last stage.

**4.2.1.4 Root Fresh Weight:** At 40 DAS, unexpectedly, the lower concentration of waste water as well as fertilizers 25%ww$N_{12.5}P_{12.5}K_{12.5}$ proved better followed by 100%ww$N_{100}P_{100}K_{100}$, 75%ww$N_{50}P_{50}K_{50}$ and TW$K_{25}N_{50}P_{25}$ (Table 24). The last treatment was also at par with TW$K_{50}N_{50}P_{25}$. The remaining two treatments were poorest in their effect. At 55 DAS, another treatment 75%ww$N_{50}P_{50}K_{50}$ improved this parameter followed by 100%ww$N_{100}P_{100}K_{100}$, 50%ww$N_{25}P_{25}K_{25}$ and 25%ww$N_{12.5}P_{12.5}K_{12.5}$. Out of remaining four treatments TW$K_{25}N_{50}P_{25}$ was at par with tap water alone. TW$K_{50}N_{50}P_{25}$ was as effective as TW$K_{12.5}N_{50}P_{25}$. While at 70 DAS, although 100%ww$N_{100}P_{100}K_{100}$ gave more root fresh weight followed by 75%ww$N_{50}P_{50}K_{50}$, the treatment 50%ww$N_{25}P_{25}K_{25}$ also recorded significant increase in root fresh weight as this treatment was also optimum for plant fresh weight. This treatment followed the 25%ww$N_{12.5}P_{12.5}K_{12.5}$ and TW$K_{12.5}N_{50}P_{25}$ and TW$K_{50}N_{50}P_{25}$ was statistically similar with TW$K_0N_0P_0$.

**4.2.1.5 Root Dry Weight:** At 40 DAS, as observed in root fresh weight 25%ww$N_{12.5}P_{12.5}K_{12.5}$ proved best and it was statistically similar in value with TW$K_{25}N_{50}P_{25}$ which was followed by 100%ww$N_{100}P_{100}K_{100}$, 75%ww$N_{50}P_{50}K_{50}$ and 50%ww$N_{25}P_{25}K_{25}$ which in turn was equaled by TW$K_{50}N_{50}P_{25}$ (Table 24). Tap water alone gave the lowest value. At 55 DAS, 75%ww$N_{50}P_{50}K_{50}$ was the optimum treatment followed by 100%ww$N_{100}P_{100}K_{100}$ and 50%ww$N_{25}P_{25}K_{25}$. While the tap water dose, TW$K_{25}N_{50}P_{25}$ was at par with 25%ww$N_{12.5}P_{12.5}K_{12.5}$ and TW$K_0N_0P_0$. The remaining two treatments TW$K_{12.5}N_{50}P_{25}$, TW$K_{50}N_{50}P_{25}$ were equally effective and poorest among all treatments. At the harvest stage, 100%ww$N_{100}P_{100}K_{100}$ proved best followed by 75%ww$N_{50}P_{50}K_{50}$, 50%ww$N_{25}P_{25}K_{25}$, 25%ww$N_{12.5}P_{12.5}K_{12.5}$, TW$K_{12.5}N_{50}P_{25}$, TW$K_{50}N_{50}P_{25}$, TW alone and TW$K_{25}N_{50}P_{25}$ in that order. These treatments were statistically different with one another. Among the TW treatments, TW$K_{12.5}N_{50}P_{25}$ proved best and among the wastewater 100%ww$N_{100}P_{100}K_{100}$ was the best at harvest stage. Like plant fresh weight, root dry weight also increased up to the last sampling.

**4.2.1.6 Root Diameter:** At 40 DAS, TW$K_{25}N_{50}P_{25}$ showed the maximum diameter than the other treatments and followed by 100%ww$N_{100}P_{100}K_{100}$. The later treatment was statistically similar with 25%ww$N_{12.5}P_{12.5}K_{12.5}$ which in turn was followed by 75%ww$N_{50}P_{50}K_{50}$. 50%ww$N_{25}P_{25}K_{25}$ on the one hand and was at par with TW$K_{50}N_{50}P_{25}$ while on the other hand it was equaled by TW$K_{12.5}N_{50}P_{25}$. Tap water alone gave the lowest diameter of turnip root (Table 24). At 55 and 70 DAS, 75%ww$N_{50}P_{50}K_{50}$ showed the maximum diameter. It showed an increase of 217.46% and 156% respectively over TW alone. At 55 DAS, 75%ww$N_{50}P_{50}K_{50}$ followed by the 100%ww$N_{100}P_{100}K_{100}$, 50%ww$N_{25}P_{25}K_{25}$ and 25%ww$N_{12.5}P_{12.5}K_{12.5}$. While at 70 DAS, 50%ww$N_{25}P_{25}K_{25}$ was statistically similar with 75%ww$N_{50}P_{50}K_{50}$ followed by 25%ww$N_{12.5}P_{12.5}K_{12.5}$ and TW$K_{12.5}N_{50}P_{25}$ which in turn was at par with TW alone. Since the tap water was equaled by 100%ww$N_{100}P_{100}K_{100}$ therefore proving excessive for root growth. It may also be noted that root diameter increased up to the last stage specially under the 25%, 50% and 75% wastewater while it decreased under 100%ww.

**Table: 23 Effect of TW with four levels of potassium and different concentrations of WW with four levels of NPK on plant fresh weight (g plant$^{-1}$), plant dry weight (g plant$^{-1}$) and plant height (cm plant$^{-1}$) of turnip (*Brassica rapa*) at three stages of sampling.**

| Treatments | Plant Fresh Weight | | | Plant Dry Weight | | | Plant Height | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | 55 | 70 | 40 | 55 | 70 | 40 | 55 | 70 |
| $TWN_0P_0K_0$ | 7.84 | 13.84 | 18.07 | 0.66 | 1.11 | 1.51 | 26.6 | 30.5 | 32.0 |
| $TWN_{50}P_{25}K_{12.5}$ | 9.59 | 17.71 | 25.33 | 0.90 | 1.42 | 1.97 | 38.0 | 30.5 | 38.0 |
| $TWN_{50}P_{25}K_{25}$ | 19.64 | 20.58 | 23.81 | 1.60 | 1.65 | 1.88 | 34.0 | 38.0 | 34.4 |
| $TW\ N_{50}P_{25}K_{50}$ | 16.23 | 16.49 | 32.03 | 1.22 | 1.33 | 2.48 | 34.0 | 32.0 | 43.0 |
| $25\%wwN_{12.5}P_{12.5}K_{12.5}$ | 14.37 | 19.67 | 43.09 | 1.26 | 1.72 | 3.96 | 26.6 | 35.2 | 42.0 |
| $50\%wwN_{25}P_{25}K_{25}$ | 12.03 | 32.05 | 52.30 | 0.92 | 2.56 | 4.72 | 30.5 | 35.8 | 44.5 |
| $75\%wwN_{50}P_{50}K_{50}$ | 15.42 | 31.86 | 50.80 | 1.23 | 2.83 | 4.81 | 30.5 | 35.0 | 45.0 |
| $100\%wwN_{100}P_{100}K_{100}$ | 17.28 | 38.56 | 40.80 | 1.43 | 3.05 | 3.77 | 35.5 | 38.0 | 43.0 |
| **C.D. at 5%** | **1.122** | **1.970** | **2.928** | **0.092** | **0.162** | **0.260** | **2.036** | **2.068** | **2.258** |

**Table: 24 Effect of TW with four levels of potassium and different concentrations of WW with four levels of NPK on root fresh weight (g plant$^{-1}$), root dry weight (g plant$^{-1}$) and root diameter (cm) of turnip (*Brassica rapa*) at three stages of sampling.**

| Treatments | Root Fresh Weight | | | Root Dry Weight | | | Root Diameter | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | 55 | 70 | 40 | 55 | 70 | 40 | 55 | 70 |
| $TWN_0P_0K_0$ | 0.23 | 1.35 | 3.02 | 0.03 | 0.13 | 0.27 | 0.40 | 0.63 | 1.25 |
| $TWN_{50}P_{25}K_{12.5}$ | 0.38 | 0.69 | 4.78 | 0.04 | 0.08 | 0.36 | 0.60 | 0.55 | 1.37 |
| $TWN_{50}P_{25}K_{25}$ | 0.75 | 1.37 | 1.97 | 0.14 | 0.16 | 0.18 | 1.20 | 1.03 | 0.50 |
| $TW\ N_{50}P_{25}K_{50}$ | 0.74 | 0.81 | 3.29 | 0.06 | 0.07 | 0.29 | 0.67 | 0.60 | 1.10 |
| $25\%wwN_{12.5}P_{12.5}K_{12.5}$ | 1.43 | 1.66 | 5.30 | 0.13 | 0.13 | 0.45 | 0.95 | 1.15 | 1.90 |
| $50\%wwN_{25}P_{25}K_{25}$ | 0.64 | 3.78 | 12.41 | 0.06 | 0.29 | 0.97 | 0.66 | 1.25 | 3.10 |
| $75\%wwN_{50}P_{50}K_{50}$ | 1.11 | 6.63 | 13.18 | 0.09 | 0.63 | 1.14 | 0.80 | 2.00 | 3.20 |
| $100\%wwN_{100}P_{100}K_{100}$ | 1.24 | 5.06 | 19.09 | 0.11 | 0.54 | 1.66 | 1.00 | 1.50 | 1.20 |
| **C.D. at 5%** | **0.067** | **0.262** | **0.770** | **0.007** | **0.025** | **0.065** | **0.064** | **0.090** | **0.156** |

N.B: Subscript values denote the amount of phosphorus (NPK) in kg ha$^{-1}$. C.D: Critical Difference, DAS: Days After Sowing, WW: Wastewater, TW: Tap Water

**4.2.1.7 Leaf Fresh Weight:** At 40 DAS, $TWK_{25}N_{50}P_{25}$ proving superior over other treatments and critically different with other treatments and also closely followed by $100\%wwN_{100}P_{100}K_{100}$ and $TWK_{50}N_{50}P_{25}$ and the last two were statistically at par (Table 25). Out of the remaining treatments $75\%wwN_{50}P_{50}K_{50}$ was followed by $25\%wwN_{12.5}P_{12.5}K_{12.5}$, $50\%wwN_{25}P_{25}K_{25}$, $TWK_{12.5}N_{50}P_{25}$ and tap water alone in that order. $50\%wwN_{25}P_{25}K_{25}$ gave an increase of 49.67% over TW alone. At 55 DAS, $100\%wwN_{100}P_{100}K_{100}$ showed the maximum leaf fresh weight and it was critically different with other treatments. $50\%wwN_{25}P_{25}K_{25}$ closely followed it giving 168.21 and 126.34% more leaf fresh weight over tap water alone. Thus at 55 DAS, higher dose of NPK and higher concentration of wastewater ($100\%wwN_{100}P_{100}K_{100}$) may be suggested if the crop has to be taken up earlier for commercial marketing to be consumed as leafy vegetable. The treatment $25\%wwN_{12.5}P_{12.5}K_{12.5}$ was equal to $TWK_{25}N_{50}P_{25}$, on the other hand it was also similar with $TWK_{12.5}N_{50}P_{25}$. At 70 DAS, $50\%wwN_{25}P_{25}K_{25}$ was at par with $25\%wwN_{12.5}P_{12.5}K_{12.5}$ and $75\%wwN_{50}P_{50}K_{50}$ and followed by $TWK_{50}N_{50}P_{25}$ thus proving the optimum dose. Out of other treatments $100\%wwN_{100}P_{100}K_{100}$ showed similar effect with $TWK_{12.5}N_{50}P_{25}$ and $TWK_{25}N_{50}P_{25}$ and tap water alone was the poorest. The leaf fresh weight also increased consistently increased with the increase in plant age.

**4.2.1.8 Leaf Dry Weight:** At 40 DAS, $TWK_{25}N_{50}P_{25}$ showed the maximum leaf dry weight followed by $100\%wwN_{100}P_{100}K_{100}$ (Table 25). The treatment $TWK_{50}N_{50}P_{25}$ showed similar effect with $75\%wwN_{50}P_{50}K_{50}$ and $25\%wwN_{12.5}P_{12.5}K_{12.5}$. Whereas at 55 DAS, $100\%wwN_{100}P_{100}K_{100}$ showed the maximum leaf dry weight and it was critically different with other treatments. $50\%wwN_{25}P_{25}K_{25}$ closely followed it and it was at par with $75\%wwN_{50}P_{50}K_{50}$ while $25\%wwN_{12.5}P_{12.5}K_{12.5}$ was at par with $TWK_{25}N_{50}P_{25}$. Similarly the treatment $TWK_{12.5}N_{50}P_{25}$ was equaled by $TWK_{50}N_{50}P_{25}$ and tap water alone was the least effective treatment. At 70 DAS, again comparatively lower dose and concentration $50\%wwN_{25}P_{25}K_{25}$ showed the maximum leaf dry weight and it was statistically similar with $75\%wwN_{50}P_{50}K_{50}$ which in turn was at par with $25\%wwN_{12.5}P_{12.5}K_{12.5}$. $100\%wwN_{100}P_{100}K_{100}$ was equally effective with that of $TWK_{50}N_{50}P_{25}$. Leaf dry weight, like fresh weight also increased up to the last sampling.

**4.2.1.9 Leaf Number:** The treatment effect for this parameter was not as distinct as observed earlier at 40 DAS. Thus leaf number was equally affected by the treatments $TWK_{25}N_{50}P_{25}$, $TWK_{12.5}N_{50}P_{25}$, $50\%wwN_{25}P_{25}K_{25}$ and $100\%wwN_{100}P_{100}K_{100}$. Similarly, $TWK_{50}N_{50}P_{25}$ was at par with $25\%wwN_{12.5}P_{12.5}K_{12.5}$, $75\%wwN_{50}P_{50}K_{50}$ and TW alone (Table 25). At 55 DAS, $100\%wwN_{100}P_{100}K_{100}$ showed the maximum leaf number and it was critically different with other treatments which may be advised at 55 DAS, for early commercial marketing due to higher leaf number and higher fresh weight of leaves. It showed 64.92% more leaf number over $TWK_0N_0P_0$. $50\%wwN_{25}P_{25}K_{25}$ was found statistically similar with $75\%wwN_{50}P_{50}K_{50}$ as well as with TW alone, $TWK_{12.5}N_{50}P_{25}$ and $TWK_{50}N_{50}P_{25}$. At 70 DAS, $TWK_{25}N_{50}P_{25}$ proved comparatively better followed by the $100\%wwN_{100}P_{100}K_{100}$ and this treatment was also critically different with other treatments.

### 4.2.2 *Heavy metal content in root and leaf of turnip*

**4.2.2.1 Cadmium:** In case of root in general higher concentration was present in treatments containing wastewater. It was maximum at 40 DAS, in $50\%wwN_{25}P_{25}K_{25}$ followed by $75\%wwN_{50}P_{50}K_{50}$. $25\%wwN_{12.5}P_{12.5}K_{12.5}$ and $100\%wwN_{100}P_{100}K_{100}$ (Table 26). While remaining four treatments of TW with various K doses were at par with one another. At 55 DAS, $25\%wwN_{12.5}P_{12.5}K_{12.5}$ showed the maximum Cd concentration followed by $50\%wwN_{25}P_{25}K_{25}$ and $100\%wwN_{100}P_{100}K_{100}$.While $75\%wwN_{50}P_{50}K_{50}$ was at par with $TWK_{50}N_{50}P_{25}$ and $TWK_{25}N_{50}P_{25}$ was at par with $TWK_{12.5}N_{50}P_{25}$. Contrary to earlier stages at 70 DAS, $100\%wwN_{100}P_{100}K_{100}$ showed the maximum concentration followed by $75\%wwN_{50}P_{50}K_{50}$, $25\%wwN_{12.5}P_{12.5}K_{12.5}$ and $50\%wwN_{25}P_{25}K_{25}$ and all the treatments were critically different with each other. Among the TW treatments, $TWK_{25}N_{50}P_{25}$ gave the maximum Cd concentration followed by $TWK_{12.5}N_{50}P_{25}$, $TWK_{50}N_{50}P_{25}$ and TW alone. Its concentration decreased with growth up to 55 DAS, and again it increased marginally at harvest stage. Cd is comparatively more in roots than in leaves. In case of leaf also its concentration was higher in wastewater treatments as compared to TW treatments. At 40 DAS, $100\%wwN_{100}P_{100}K_{100}$ showed the maximum concentration (62.5% increases over TW) and was at par with $TWK_{50}N_{50}P_{25}$ and the later treatment was at par with $75\%wwN_{50}P_{50}K_{50}$ which was followed by $50\%wwN_{25}P_{25}K_{25}$ While $TWK_{12.5}N_{50}P_{25}$, $TWK_{25}N_{50}P_{25}$ and TW alone were statistically similar giving the lowest values. At 55

**Table: 25 Effect of TW with four levels of potassium and different concentrations of WW with four levels of NPK on leaf fresh weight (g plant$^{-1}$), leaf dry weight (g plant$^{-1}$) and leaf number (plant$^{-1}$) of turnip (*Brassica rapa*) at three stages of sampling.**

| Treatments | Leaf Fresh Weight | | | Leaf Dry Weight | | | Leaf Number | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | 55 | 70 | 40 | 55 | 70 | 40 | 55 | 70 |
| $TWN_0P_0K_0$ | 7.61 | 12.49 | 15.05 | 0.63 | 0.98 | 1.24 | 7.00 | 6.67 | 8.00 |
| $TWN_{50}P_{25}K_{12.5}$ | 9.21 | 17.02 | 20.55 | 0.86 | 1.34 | 1.61 | 7.67 | 6.67 | 7.67 |
| $TWN_{50}P_{25}K_{25}$ | 18.89 | 19.21 | 21.84 | 1.46 | 1.49 | 1.70 | 8.00 | 9.00 | 10.0 |
| TW $N_{50}P_{25}K_{50}$ | 15.49 | 15.68 | 28.74 | 1.16 | 1.26 | 2.19 | 7.33 | 6.67 | 8.33 |
| 25%ww$N_{12.5}P_{12.5}K_{12.5}$ | 12.94 | 18.01 | 37.79 | 1.13 | 1.59 | 3.51 | 7.00 | 8.00 | 7.33 |
| 50%ww$N_{25}P_{25}K_{25}$ | 11.39 | 28.27 | 39.89 | 0.86 | 2.27 | 3.75 | 8.00 | 7.00 | 8.00 |
| 75%ww$N_{50}P_{50}K_{50}$ | 14.31 | 25.23 | 37.62 | 1.14 | 2.20 | 3.67 | 7.00 | 7.33 | 8.00 |
| 100%ww$N_{100}P_{100}K_{100}$ | 16.04 | 33.50 | 21.71 | 1.32 | 2.51 | 2.11 | 8.00 | 11.00 | 9.33 |
| **C.D. at 5%** | **1.061** | **1.737** | **2.293** | **0.086** | **0.139** | **0.206** | **0.602** | **0.616** | **0.664** |

N.B: Subscript values denote the amount of phosphorus (NPK) in kg ha$^{-1}$. N.D: Not Detectable, DAS: Days After Sowing, WW: Wastewater, TW: Tap Water

DAS, its concentration was maximum in $75\%wwN_{50}P_{50}K_{50}$ followed by $TWK_{12.5}N_{50}P_{25}$ and $50\%wwN_{25}P_{25}K_{25}$ and the last treatment was at par with $25\%wwN_{12.5}P_{12.5}K_{12.5}$. While at harvest stage, $TWK_{50}N_{50}P_{25}$ showed the maximum concentration and it was different with other treatments. $TWK_{12.5}N_{50}P_{25}$ was at par with $100\%wwN_{100}P_{100}K_{100}$ and $75\%wwN_{50}P_{50}K_{50}$. Cd concentration decreased with increase in growth in most of the treatments.

**4.2.2.2 Chromium:** Chromium was not detected in root as well as in leaf at all the three stages of sampling (Table 27).

**4.2.2.3 Nickel:** In general, it was decreased with increase in concentration of wastewater at 40 DAS, while at 55 and 70 DAS, it was increased with increased concentration. Wastewater treatment generally increased the concentration of Ni. At 40 DAS, it was maximum in $50\%wwN_{25}P_{25}K_{25}$ and at par with $75\%wwN_{50}P_{50}K_{50}$. $25\%wwN_{12.5}P_{12.5}K_{12.5}$ was at par with $100\%wwN_{100}P_{100}K_{100}$. While $TWK_{12.5}N_{50}P_{25}$ was equally effective to $TWK_{25}N_{50}P_{25}$. At 55 DAS, $100\%wwN_{100}P_{100}K_{100}$ accumulated maximum Ni concentration followed by $TWK_{25}N_{50}P_{25}$, $TWK_{12.5}N_{50}P_{25}$, $TWK_{50}N_{50}P_{25}$ and $25\%wwN_{12.5}P_{12.5}K_{12.5}$ (Table 28). The last treatment was at par with $75\%wwN_{50}P_{50}K_{50}$ followed by $50\%wwN_{25}P_{25}K_{25}$. At harvest stage also, $100\%wwN_{100}P_{100}K_{100}$ recorded the maximum concentration which was followed by $75\%wwN_{50}P_{50}K_{50}$ and it was equal to $TWK_{25}N_{50}P_{25}$. Compared to leaf, Ni concentration was more in root. Its concentration was also high in wastewater treatments as compared to TW treatments. Ni concentration increased up to $K_{25}$ in TW treatments. In case of leaf at 40 DAS, $50\%wwN_{25}P_{25}K_{25}$, gave more Ni concentration and was at par with $75\%wwN_{50}P_{50}K_{50}$, $25\%wwN_{12.5}P_{12.5}K_{12.5}$ and $TWK_{12.5}N_{50}P_{25}$ and the last treatment was at par with $100\%wwN_{100}P_{100}K_{100}$. At second stage $TWK_{25}N_{50}P_{25}$ showed higher Ni concentration. It was followed by $TWK_{12.5}N_{50}P_{25}$, $TWK_{50}N_{50}P_{25}$, $100\%wwN_{100}P_{100}K_{100}$ and $25\%wwN_{12.5}P_{12.5}K_{12.5}$ and the last treatment was also at par with TW alone, and $50\%wwN_{25}P_{25}K_{25}$. While at harvest stage, it was more in $TWK_{25}N_{50}P_{25}$ followed by $TWK_{50}N_{50}P_{25}$ and $TWK_{12.5}N_{50}P_{25}$ and the latter treatment was at par with $100\%wwN_{100}P_{100}K_{100}$ and $75\%wwN_{50}P_{50}K_{50}$. While TW alone showed the similar effect with $25\%wwN_{12.5}P_{12.5}K_{12.5}$ and $50\%wwN_{25}P_{25}K_{25}$.

**Table: 26 Effect of TW with four levels of potassium and different concentrations of WW with four levels of NPK on cadmium (mg/kg DW) content in root and leaf of turnip (*Brassica rapa*) at three stages of sampling.**

| Treatments | Cadmium in root | | | Cadmium in leaf | | |
|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | |
| | 40 | 55 | 70 | 40 | 55 | 70 |
| $TWN_0P_0K_0$ | 2.50 | 0.90 | 1.50 | 4.00 | 0.90 | 2.00 |
| $TWN_{50}P_{25}K_{12.5}$ | 3.90 | 2.50 | 2.75 | 4.40 | 4.10 | 2.35 |
| $TWN_{50}P_{25}K_{25}$ | 3.10 | 2.80 | 3.50 | 4.10 | 2.10 | 3.58 |
| $TW\ N_{50}P_{25}K_{50}$ | 3.70 | 4.40 | 2.15 | 6.40 | 1.40 | 4.13 |
| $25\%wwN_{12.5}P_{12.5}K_{12.5}$ | 10.8 | 8.00 | 6.00 | 5.50 | 2.80 | 3.25 |
| $50\%wwN_{25}P_{25}K_{25}$ | 26.0 | 6.00 | 5.00 | 5.50 | 2.80 | 3.00 |
| $75\%wwN_{50}P_{50}K_{50}$ | 15.8 | 4.30 | 6.50 | 6.00 | 5.30 | 2.25 |
| $100\%wwN_{100}P_{100}K_{100}$ | 11.0 | 4.80 | 7.75 | 6.50 | 1.80 | 2.25 |
| **C.D. at 5%** | **1.439** | **0.373** | **0.389** | **0.415** | **0.252** | **0.245** |

**Table: 27 Effect of TW with four levels of potassium and different concentrations of WW with four levels of NPK on chromium (mg/kg DW) content in root and leaf of turnip (*Brassica rapa*) at three stages of sampling.**

| Treatments | Chromium in root | | | Chromium in leaf | | |
|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | |
| | 40 | 55 | 70 | 40 | 55 | 70 |
| $TWN_0P_0K_0$ | | | | | | |
| $TWN_{50}P_{25}K_{12.5}$ | | | | | | |
| $TWN_{50}P_{25}K_{25}$ | | | | | | |
| $TW\ N_{50}P_{25}K_{50}$ | | | | | | |
| $25\%wwN_{12.5}P_{12.5}K_{12.5}$ | | | N.D. | | | |
| $50\%wwN_{25}P_{25}K_{25}$ | | | | | | |
| $75\%wwN_{50}P_{50}K_{50}$ | | | | | | |
| $100\%wwN_{100}P_{100}K_{100}$ | | | | | | |
| **C.D. at 5%** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |

N.B: Subscript values denote the amount of phosphorus (NPK) in kg $ha^{-1}$. C.D: Critical Difference, DW: Dry Weight, N.S: Non Significant, N.D: Not Detectable, DAS: Days After Sowing, WW: Wastewater, TW: Tap Water

**4.2.2.4 Iron:** It was increased with increase of wastewater concentration as well as with increase of K doses. At 40 DAS, 100%ww$N_{100}P_{100}K_{100}$ gave the maximum concentration followed by 75%ww$N_{50}P_{50}K_{50}$ (Table 29). Among the tap water treatments, TW$K_{12.5}N_{50}P_{25}$ was at par with TW$K_{25}N_{50}P_{25}$. At later stage, 75%ww$N_{50}P_{50}K_{50}$ recorded the highest Fe content which was at par with 100%ww$N_{100}P_{100}K_{100}$ and 50%ww$N_{25}P_{25}K_{25}$. TW$K_{25}N_{50}P_{25}$ was at par with TW$K_{12.5}N_{50}P_{25}$. At harvest, 100%ww$N_{100}P_{100}K_{100}$ showed the maximum concentration followed by 75%ww$N_{50}P_{50}K_{50}$ and 25%ww$N_{12.5}P_{12.5}K_{12.5}$ and this treatment was statistically similar with TW$K_{12.5}N_{50}P_{25}$ and TW$K_{50}N_{50}P_{25}$. In root its concentration generally decreased with growth of the plant. In case of leaf. Fe generally decreased with growth. At 40 DAS, it was maximum in TW$K_{12.5}N_{50}P_{25}$ and this treatment was statistically similar with TW$K_{25}N_{50}P_{25}$ while other treatments were critically different. At 55 DAS, TW$K_{25}N_{50}P_{25}$ showed the maximum Fe content followed by TW$K_{12.5}N_{50}P_{25}$ and the last treatment was at par with TW alone. At the last stage, TW$K_{25}N_{50}P_{25}$ showed the maximum concentration followed by TW$K_{12.5}N_{50}P_{25}$ and TW$K_{50}N_{50}P_{25}$. Among all the heavy metals studied, Fe concentration was comparatively more than Cd, Cr, Ni, Cu, Mn and Zn.

**4.2.2.5 Copper:** In case of root, like Cr, Cu was also absent in tap water alone and tap water with different K doses. Interestingly, the concentration of Cu was not much different in root and leaf. At 55 DAS, 25%ww$N_{12.5}P_{12.5}K_{12.5}$ showed the maximum concentration followed by 75%ww$N_{50}P_{50}K_{50}$ and the last treatment was statistically similar with 50%ww$N_{25}P_{25}K_{25}$ (Table 30). Its concentration decreased with increased concentration of wastewater. While at 70 DAS, 100%ww$N_{100}P_{100}K_{100}$ showed the maximum concentration and was at par with 25%ww$N_{12.5}P_{12.5}K_{12.5}$. Like root it was also not found in leaf of plants grown in tap water and not much difference was found in concentration with the growth of plant. At 40 DAS, comparatively lower concentration of wastewater as well as of lower fertilizer dose 25%ww$N_{12.5}P_{12.5}K_{12.5}$ showed maximum Cu concentration followed by 100%ww$N_{100}P_{100}K_{100}$. While at 55 DAS, also somewhat similar trend was noted and at 70 DAS, contrary to above observations 50%ww$N_{25}P_{25}K_{25}$ showed maximum Cu followed by 100%ww$N_{100}P_{100}K_{100}$ and the latter treatment was equaled by 25%ww$N_{12.5}P_{12.5}K_{12.5}$ which was followed by 75%ww$N_{50}P_{50}K_{50}$. Like root it was not found in leaf in the tap

**Table: 28 Effect of TW with four levels of potassium and different concentrations of WW with four levels of NPK on nickel (mg/kg DW) content in root and leaf of turnip (*Brassica rapa*) at three stages of sampling.**

| Treatments | Nickel in root | | | Nickel in leaf | | |
|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | |
| | 40 | 55 | 70 | 40 | 55 | 70 |
| $TWN_0P_0K_0$ | 55.1 | 34.0 | 47.0 | 65.2 | 30.0 | 35.0 |
| $TWN_{50}P_{25}K_{12.5}$ | 82.5 | 73.0 | 65.0 | 88.4 | 68.6 | 49.0 |
| $TWN_{50}P_{25}K_{25}$ | 75.0 | 80.0 | 80.0 | 78.0 | 77.5 | 71.3 |
| TW $N_{50}P_{25}K_{50}$ | 51.0 | 62.0 | 62.0 | 41.2 | 48.8 | 52.9 |
| $25\%wwN_{12.5}P_{12.5}K_{12.5}$ | 111.0 | 53.0 | 44.0 | 89.0 | 31.0 | 36.0 |
| $50\%wwN_{25}P_{25}K_{25}$ | 142.0 | 44.0 | 58.0 | 95.0 | 28.0 | 36.0 |
| $75\%wwN_{50}P_{50}K_{50}$ | 128.0 | 51.0 | 84.0 | 93.0 | 23.0 | 45.0 |
| $100\%wwN_{100}P_{100}K_{100}$ | 106.0 | 92.0 | 97.0 | 85.0 | 36.0 | 46.0 |
| **C.D. at 5%** | **8.081** | **5.449** | **5.815** | **6.893** | **4.230** | **4.087** |

**Table: 29 Effect of TW with four levels of potassium and different concentrations of WW with four levels of NPK on iron (mg/kg DW) content in root and leaf of turnip (*Brassica rapa*) at three stages of sampling.**

| Treatments | Iron in root | | | Iron in leaf | | |
|---|---|---|---|---|---|---|
| | Sampling Stages (DAS) | | | | | |
| | 40 | 55 | 70 | 40 | 55 | 70 |
| $TWN_0P_0K_0$ | 720 | 695 | 550 | 882 | 795 | 640 |
| $TWN_{50}P_{25}K_{12.5}$ | 938 | 756 | 893 | 1171 | 845 | 869 |
| $TWN_{50}P_{25}K_{25}$ | 903 | 769 | 558 | 1149 | 985 | 967 |
| TW $N_{50}P_{25}K_{50}$ | 951 | 687 | 891 | 1072 | 736 | 655 |
| $25\%wwN_{12.5}P_{12.5}K_{12.5}$ | 1083 | 958 | 949 | 850 | 604 | 115 |
| $50\%wwN_{25}P_{25}K_{25}$ | 1064 | 1038 | 828 | 529 | 323 | 143 |
| $75\%wwN_{50}P_{50}K_{50}$ | 1108 | 1106 | 981 | 432 | 382 | 349 |
| $100\%wwN_{100}P_{100}K_{100}$ | 1565 | 1059 | 1240 | 514 | 224 | 379 |
| **C.D. at 5%** | **87.28** | **73.74** | **73.35** | **76.96** | **58.94** | **54.14** |

N.B: Subscript values denote the amount of phosphorus (NPK) in kg $ha^{-1}$. C.D: Critical Difference, DW: Dry Weight, DAS: Days After Sowing, WW: Wastewater, TW: Tap Water

water treatments and not much difference was found in concentration with the growth of the plant. Its concentration was generally decreased with increase in growth.

**4.2.2.6 Manganese:** In case of wastewater it was decreased with increasing concentration at earlier two stages. At the last stage of sampling, similar trend was not found. It was generally decreased with growth of the plant. At 40 DAS, 50%ww$N_{25}P_{25}K_{25}$ showed the maximum followed by 75%ww$N_{50}P_{50}K_{50}$, 100%ww$N_{100}P_{100}K_{100}$, 25%ww$N_{12.5}P_{12.5}K_{12.5}$, TW$K_{12.5}N_{50}P_{25}$ and TW$K_{50}N_{50}P_{25}$ and the last treatment was at par with TW$K_{25}N_{50}P_{25}$. At 55 DAS, 25%ww$N_{12.5}P_{12.5}K_{12.5}$, gave maximum Mn concentration and it was at par with 50%ww$N_{25}P_{25}K_{25}$, and 75%ww$N_{50}P_{50}K_{50}$. Among the K treatments TW$K_{50}N_{50}P_{25}$ was at par with TW$K_{25}N_{50}P_{25}$ and TW$K_{12.5}N_{50}P_{25}$. At 70 DAS, 75%ww$N_{50}P_{50}K_{50}$ showed the maximum concentration followed by 100%ww$N_{100}P_{100}K_{100}$, 25%ww$N_{12.5}P_{12.5}K_{12.5}$ and 50%ww$N_{25}P_{25}K_{25}$. In case of root, its concentration generally increased with increase of K doses in TW (Table 31). In case of leaf, in general, Mn concentration decreased with growth. At 40 DAS, 75%ww$N_{50}P_{50}K_{50}$ showed the maximum concentration followed by 100%ww$N_{100}P_{100}K_{100}$ and 50%ww$N_{25}P_{25}K_{25}$ and the last treatment was at par with 25%ww$N_{12.5}P_{12.5}K_{12.5}$. Among the TW treatments, TW$K_{12.5}N_{50}P_{25}$, was at par with TW$K_{50}N_{50}P_{25}$ and TW$K_{25}N_{50}P_{25}$. In most of the cases it was decreased at 55 DAS, but again increased at harvest stage. It was maximum in 75%ww$N_{50}P_{50}K_{50}$ at 40 and 70 DAS, but at 55 DAS, 100%ww$N_{100}P_{100}K_{100}$ showed more Mn concentration giving an increase of 128.61% over TW alone. At 70 DAS, 75%ww$N_{50}P_{50}K_{50}$ gave the maximum concentration and it was at par with 50%ww$N_{25}P_{25}K_{25}$ and recorded an increase of 54.55% over TW alone.

**4.2.2.7 Zinc:** Among the wastewater treatments its concentration generally decreased with increased concentrations. Zn was maximum in 50%ww$N_{25}P_{25}K_{25}$ among wastewater treatments at all the samplings. At 40 DAS, 50%ww$N_{25}P_{25}K_{25}$ giving maximum value followed by 75%ww$N_{50}P_{50}K_{50}$ was at par with 25%ww$N_{12.5}P_{12.5}K_{12.5}$ (Table 32). At later stage also 50%ww$N_{25}P_{25}K_{25}$ showed maximum concentration followed by 25%ww$N_{12.5}P_{12.5}K_{12.5}$ and 100%ww$N_{100}P_{100}K_{100}$. Last treatment was at par with 75%ww$N_{50}P_{50}K_{50}$. At 70 DAS, again 50%ww$N_{25}P_{25}K_{25}$ was responsible for maximum concentration of Zn followed by 75%ww$N_{50}P_{50}K_{50}$, and last treatment was at par with 100%ww$N_{100}P_{100}K_{100}$, followed by 25%ww$N_{12.5}P_{12.5}K_{12.5}$, TW$K_{50}N_{50}P_{25}$,

$TWK_{25}N_{50}P_{25}$ and $TWK_{12.5}N_{50}P_{25}$ and the last one was at par with TW alone. It was more in root than the leaves. In case of leaf, Zn concentration generally increased with K doses as well as with wastewater treatments. It was also decreased with growth of the plant. Among all the wastewater treatments, $100\%wwN_{100}P_{100}K_{100}$ showed the maximum concentration. At 40 DAS, $100\%wwN_{100}P_{100}K_{100}$ was more effective in Zn concentration and it was at par with $TWK_{12.5}N_{50}P_{25}$ and showed an increase 83.82% over TW alone. At 55 DAS, $100\%wwN_{100}P_{100}K_{100}$ again accumulated more Zn in leaf followed by $75\%wwN_{50}P_{50}K_{50}$ which was at par with $25\%wwN_{12.5}P_{12.5}K_{12.5}$. At 70 DAS, also $100\%wwN_{100}P_{100}K_{100}$ showed maximum Zn followed by $25\%wwN_{12.5}P_{12.5}K_{12.5}$, while the last treatment was at par with $TWK_{50}N_{50}P_{25}$, which in turn was at par with $50\%wwN_{25}P_{25}K_{25}$.

**Table: 30 Effect of TW with four levels of potassium and different concentrations of WW with four levels of NPK on copper (mg/kg DW) content in root and leaf of turnip (*Brassica rapa*) at three stages of sampling.**

| Treatments | Copper in root | | | Copper in leaf | | |
|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | |
| | 40 | 55 | 70 | 40 | 55 | 70 |
| $TWN_0P_0K_0$ | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. |
| $TWN_{50}P_{25}K_{12.5}$ | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. |
| $TWN_{50}P_{25}K_{25}$ | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. |
| $TW\ N_{50}P_{25}K_{50}$ | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. |
| $25\%wwN_{12.5}P_{12.5}K_{12.5}$ | N.D. | 3.50 | 2.00 | 5.00 | 4.50 | 2.50 |
| $50\%wwN_{25}P_{25}K_{25}$ | N.D. | 2.00 | 1.50 | 2.50 | 3.00 | 3.00 |
| $75\%wwN_{50}P_{50}K_{50}$ | N.D. | 2.00 | 1.00 | 2.00 | 3.00 | 2.00 |
| $100\%wwN_{100}P_{100}K_{100}$ | N.D. | 1.00 | 2.00 | 3.00 | 4.50 | 2.50 |
| **C.D. at 5%** | **NS** | **0.132** | **0.092** | **0.667** | **0.197** | **0.142** |

**Table: 31 Effect of TW with four levels of potassium and different concentrations of WW with four levels of NPK on manganese (mg/kg DW) content in root and leaf of turnip (*Brassica rapa*) at three stages of sampling.**

| | Manganese in root | | | Manganese in leaf | | |
|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | |
| Treatments | 40 | 55 | 70 | 40 | 55 | 70 |
| $TWN_0P_0K_0$ | 83.0 | 48.0 | 58.0 | 112.4 | 74.8 | 99.0 |
| $TWN_{50}P_{25}K_{12.5}$ | 165.0 | 90.0 | 85.0 | 137.0 | 128.8 | 118.6 |
| $TWN_{50}P_{25}K_{25}$ | 117.0 | 95.0 | 96.0 | 128.2 | 103.2 | 123.5 |
| $TW\ N_{50}P_{25}K_{50}$ | 118.0 | 95.6 | 101.0 | 136.8 | 100.6 | 99.6 |
| $25\%wwN_{12.5}P_{12.5}K_{12.5}$ | 174.0 | 204.0 | 167.0 | 166.0 | 109.0 | 118.0 |
| $50\%wwN_{25}P_{25}K_{25}$ | 274.0 | 196.0 | 148.0 | 166.0 | 143.0 | 151.0 |
| $75\%wwN_{50}P_{50}K_{50}$ | 254.0 | 194.0 | 210.0 | 203.0 | 113.0 | 153.0 |
| $100\%wwN_{100}P_{100}K_{100}$ | 236.0 | 178.0 | 198.0 | 189.0 | 171.0 | 135.0 |
| **C.D. at 5%** | **15.91** | **12.01** | **11.40** | **12.93** | **10.21** | **10.56** |

N.B: Subscript values denote the amount of phosphorus (NPK) in kg $ha^{-1}$. C.D: Critical Difference, DW: Dry Weight, N.S: Non Significant, N.D: Not Detectable, DAS: Days After Sowing, WW: Wastewater, TW: Tap Water

**Table: 32 Effect of TW with four levels of potassium and different concentrations of WW with four levels of NPK on zinc (mg/kg DW) content in root and leaf of turnip (*Brassica rapa*) at three stages of sampling.**

| Treatments | Zinc in root | | | Zinc in leaf | | |
|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | |
| | 40 | 55 | 70 | 40 | 55 | 70 |
| $TWN_0P_0K_0$ | 82.0 | 40.0 | 42.0 | 81.6 | 46.0 | 42.5 |
| $TWN_{50}P_{25}K_{12.5}$ | 98.0 | 46.0 | 43.0 | 144.8 | 87.0 | 83.6 |
| $TWN_{50}P_{25}K_{25}$ | 95.0 | 60.0 | 57.7 | 116.0 | 93.4 | 92.8 |
| TW $N_{50}P_{25}K_{50}$ | 111.0 | 92.0 | 72.8 | 98.4 | 83.6 | 102.1 |
| 25%ww$N_{12.5}P_{12.5}K_{12.5}$ | 198.0 | 156.0 | 141.0 | 110.0 | 105.0 | 104.0 |
| 50%ww$N_{25}P_{25}K_{25}$ | 220.0 | 190.0 | 191.0 | 98.0 | 99.0 | 95.0 |
| 75%ww$N_{50}P_{50}K_{50}$ | 199.0 | 141.0 | 180.0 | 86.0 | 109.0 | 87.0 |
| 100%ww$N_{100}P_{100}K_{100}$ | 185.0 | 143.0 | 173.0 | 150.0 | 152.0 | 123.0 |
| **C.D. at 5%** | **12.37** | **9.47** | **10.14** | **9.725** | **8.270** | **7.734** |

N.B: Subscript values denote the amount of phosphorus (NPK) in kg $ha^{-1}$. C.D: Critical Difference, DW: Dry Weight, DAS: Days After Sowing, WW: Wastewater, TW: Tap Water

## 4.3 EXPERIMENT-III

### 4.3.1 *Growth and yield characteristics*

**4.3.1.1 Plant Fresh Weight:** At 40 DAS, 100%ww, whereas at 55 and 70 DAS, 50%ww proved beneficial in enhancing the plant fresh weight, giving 81.06% and 29.36% more weight at later two sampling stages (Table 33). Among the fertilizer doses, $P_{12.5}$ in general proved good showing an increase of 54.6% and 49.28% over $P_0$ at 40 and 70 DAS. While at 55 DAS, $P_{25}$ gave 104.09% more value. The interactive effect of phosphorus and wastewater proved significant at all the three sampling stages. At 40 DAS, 50%ww$P_{12.5}N_{50}$ $K_{25}$ gave the maximum plant fresh weight, which was different with other interactions and showed an increase of 95.87% over 50%ww$P_0N_0K_0$. At 55 DAS, again 50% diluted wastewater along with NPK (50%ww$P_{25}N_{50}K_{25}$) proved best followed by 50%ww$P_{12.5}N_{50}K_{25}$, 50%ww$P_{50}N_{50}K_{25}$, 100%ww$P_{25}N_{50}K_{25}$ 100%ww$P_{12.5}N_{50}K_{25}$ and 100%$P_0N_0K_0$, showing adverse effect of 100%ww. At 70 DAS, comparatively lower phosphorus dose (50%ww$P_{12.5}N_{50}K_{25}$) showed higher plant fresh weight as it recorded an increase of 92.36%, over control. It was at par with 50%ww$P_{25}N_{50}K_{25}$ indicating the usefulness of wastewater where some P can be saved. An increasing trend was observed in the plant fresh weight up to the last stage of sampling.

**4.3.1.2 Plant Dry Weight:** Like fresh weight irrigation with 50%ww also proved beneficial in enhancing the plant dry weight. It recorded 3.6%, 66.8% and 29.01% more values over 100%ww. Fertilizer doses performed differently depending upon the stage (Table 33). At 40 DAS, $P_{12.5}$ proved good showing an increase of 51.84%, while at 55 DAS, $P_{25}$ and at the last stage $P_{50}$ was more effective. At 40 DAS, among all the interactions, 50%ww$P_{12.5}N_{50}K_{25}$, gave the maximum plant dry weight followed by 100%ww$P_{25}N_{50}K_{25}$ and 50%ww$P_{25}N_{50}K_{25}$, the last treatment was statistically similar with 100%ww$P_{25}N_{50}K_{25}$. At 55 and 70 DAS, 50%ww$P_{25}N_{50}K_{25}$, was better among all other interactions and it was also found to be statistically different with other interactions. The combination, 50%ww$P_{25}N_{50}K_{25}$, followed 50%ww$P_{12.5}N_{50}K_{25}$ at 55 and 70 DAS. While at 55 DAS, on the one hand 100%ww$P_{50}N_{50}K_{25}$ was at par with 100%ww$P_{12.5}N_{50}K_{25}$ and 50%ww $P_0N_0K_0$ and on the other hand it was at par with 100%ww $P_0N_0K_0$. Like plant fresh weight, plant dry weight also increased up to the last stage of sampling.

**4.3.1.3 Plant Height:** 50%ww increased it up to 4.62% at 40 DAS, while at last stage, 100%ww was better giving an increase of 7.92% (Table 34). Among phosphorus doses, at 40 and 55 DAS, $P_{25}$ proved best as it recorded an increase of 44.67% and 55.76% over $P_0$. At first stage interaction 100%ww$P_{25}N_{50}K_{25}$, gave the maximum height, and recorded an increase of 43.62% over 50%ww$P_0N_0K_0$ followed by 50%ww$P_{12.5}N_{50}K_{25}$. The last treatment was at par with 100%ww$P_{50}N_{50}K_{25}$ and 50%ww$P_{25}N_{50}K_{25}$. At the second stage, 50%ww$P_{25}N_{50}K_{25}$ enhanced it up to 61.37%. It was followed by100%ww$P_{50}N_{50}K_{25}$ which was also at par with 50%ww$P_{12.5}N_{50}K_{25}$, 100%ww$P_{25}N_{50}K_{25}$, and 50%ww$P_{12.5}N_{50}K_{25}$. It may be noted that both concentrations of wastewater with $P_0N_0K_0$ were equally effective. At 70 DAS, 100%ww$P_{50}N_{50}K_{25}$ gave the maximum height by registering an increase of 59.0% and it was at par with 50%ww$P_{25}N_{50}K_{25}$. The last treatment was at par with 100%ww$P_{12.5}N_{50}K_{25}$. Again $P_0N_0K_0$ with the two concentration of wastewater was equal in effect and gave the lowest values.

**4.3.1.4 Root Fresh Weight:** The effect of wastewater treatments was found to be significant and 50%ww proved better in increasing this parameter and showed an increase of 5.12%, 73.22% and 24.99% over 100%ww (Table 35). At 40 and 70 DAS, $P_{50}$ proved best showing an increase of 34.87% and 104.82% respectively while at 55 DAS, $P_{25}$ was more effective recording an increase of 82.03% over $P_0$. Interaction was also significant and at 40 DAS, higher phosphatic fertilizer dose (50%ww$P_{50}N_{50}K_{25}$) showed more root growth showing an increase of 85.61% over 50%ww$P_0N_0K_0$ followed by 50%ww$P_{12.5}N_{50}K_{25}$, the last treatment being at par with 100%ww$P_{25}N_{50}K_{25}$ and 100%ww$P_0N_0K_0$. While at 55 DAS, another treatment 50%ww$P_{25}N_{50}K_{25}$ showed better root fresh weight which was different with other treatments followed by 50%ww$P_{12.5}N_{50}K_{25}$, 50%ww$P_{50}N_{50}K_{25}$ 100%ww$P_{50}N_{50}K_{25}$ and 100%ww$P_{25}N_{50}K_{25}$. While at 70 DAS, again 50%ww$P_{25}N_{50}K_{25}$ proved good and it was equaled by 100%ww$P_{50}N_{50}K_{25}$ showing adverse effect of 100%ww with higher P dose. Like plant fresh weight, root fresh weight also increased up to the last stage of sampling.

**Table: 33 Effect of 50%ww and 100%ww on plant fresh weight (g $plant^{-1}$), plant dry weight (g $plant^{-1}$) of turnip (*Brassica rapa*) under different levels of phosphorus.**

| | Plant fresh weight | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $P_0$ | 15.98 | 16.49 | 16.24 | 28.71 | 29.27 | 28.99 | 57.7 | 59.3 | 58.5 |
| $P_{12.5}$ | 31.30 | 18.90 | 25.10 | 56.67 | 33.0 | 44.84 | 111.0 | 63.67 | 87.33 |
| $P_{25}$ | 18.75 | 28.33 | 23.54 | 85.0 | 33.33 | 59.17 | 106.3 | 67.33 | 86.83 |
| $P_{50}$ | 17.80 | 21.73 | 19.77 | 51.0 | 26.67 | 38.84 | 80.67 | 84.67 | 82.67 |
| Mean | 20.96 | 21.36 | | 55.35 | 30.57 | | 88.92 | 68.74 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 0.383 | 2.092 | 3.569 |
| Treatment | 0.542 | 2.959 | 5.048 |
| Interaction | 0.766 | 4.184 | 7.139 |

| | Plant dry weight | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $P_0$ | 1.58 | 1.68 | 1.63 | 2.95 | 2.74 | 2.85 | 5.08 | 4.76 | 4.92 |
| $P_{12.5}$ | 3.16 | 1.79 | 2.48 | 5.09 | 3.20 | 4.15 | 9.07 | 5.56 | 7.32 |
| $P_{25}$ | 1.88 | 2.43 | 2.16 | 8.39 | 3.95 | 6.17 | 9.89 | 5.53 | 7.71 |
| $P_{50}$ | 1.44 | 1.88 | 1.66 | 4.97 | 2.94 | 3.96 | 7.76 | 8.80 | 8.28 |
| Mean | 2.02 | 1.95 | | 5.35 | 3.21 | | 7.95 | 6.16 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 0.061 | 0.205 | 0.318 |
| Treatment | 0.086 | 0.289 | 0.450 |
| Interaction | 0.121 | 0.409 | 0.636 |

N.B: Subscript values denote the amount of phosphorus (P) in kg $ha^{-1}$. A uniform dose of nitrogen @ 50 kg $ha^{-1}$ ($N_{50}$) and of potassium @ 25 kg $ha^{-1}$ ($K_{25}$) was also applied basally. C.D: Critical Difference, DAS: Days After Sowing, WW: Wastewater.

**Table: 34 Effect of 50%ww and 100%ww on plant height (cm plant$^{-1}$) of turnip (*Brassica rapa*) under different levels of phosphorus.**

| | Plant height | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $P_0$ | 23.3 | 20.3 | 21.8 | 24.1 | 22.0 | 23.1 | 25.8 | 29.0 | 27.4 |
| $P_{12.5}$ | 30.5 | 21.0 | 25.8 | 33.5 | 34.8 | 34.2 | 34.0 | 37.8 | 35.9 |
| $P_{25}$ | 29.8 | 33.2 | 31.5 | 39.0 | 34.0 | 36.5 | 40.4 | 36.5 | 38.5 |
| $P_{50}$ | 26.0 | 29.8 | 27.9 | 30.5 | 35.4 | 33.0 | 33.4 | 41.0 | 37.2 |
| Mean | 27.4 | 26.1 | | 31.8 | 31.6 | | 33.4 | 36.1 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 1.454 | NS | 1.579 |
| Treatment | 1.642 | 1.762 | 1.819 |
| Interaction | 1.907 | 2.077 | 2.158 |

N.B: Subscript values denote the amount of phosphorus (P) in kg ha$^{-1}$. A uniform dose of nitrogen @ 50 kg ha$^{-1}$ ($N_{50}$) and of potassium @ 25 kg ha$^{-1}$ ($K_{25}$) was also applied basally. C.D: Critical Difference, N.S: Non Significant, DAS: Days After Sowing, WW: Wastewater.

**4.3.1.5 Root Dry Weight:** Effect of wastewater was significant. Thus 50%ww recorded an increase of 20.69%, 110.2% and 24.18% dry weight over 100%ww (Table 35). At 40 and 70 DAS, $P_{50}$ proved best and showed an increase of 30.91% and 117.92% over $P_0$. While at 55 DAS, $P_{25}$ was optimum and showed an increase of 85.28%. Among interactions at 40 DAS, 50%ww$P_{50}N_{50}K_{25}$ gave the maximum root dry weight as it showed an increase of 51.85% over 50%ww$P_0N_0K_0$ and was critically different with other combinations. It was followed by 50%ww$P_{12.5}N_{50}K_{25}$ which in turn was equal to 50%ww$P_{25}N_{50}K_{25}$. On the one hand 100%ww$P_0N_0K_0$ was at par with 100%ww$P_{25}N_{50}K_{25}$, which in turn was at par with 50%ww$P_0N_0K_0$ and 100%ww$P_{12.5}N_{50}K_{25}$. At 55 DAS, again NPK with lower concentration of wastewater (50%ww$P_{25}N_{50}K_{25}$) proved more effective followed by 50%ww$P_{12.5}N_{50}K_{25}$, 50%ww$P_{50}N_{50}K_{25}$, 100%ww$P_0N_0K_0$ and 100%ww$P_{50}N_{50}K_{25}$. At 70 DAS, 50%ww$P_{25}N_{50}K_{25}$ proved good followed by 100%ww$P_{50}N_{50}K_{25}$, 50%ww$P_{50}N_{50}K_{25}$, 50%ww$P_{12.5}N_{50}K_{25}$ and 100%ww$P_0N_0K_0$. The last treatment was at par with 100%ww$P_{12.5}N_{50}K_{25}$ which in turn was at par with 100%ww$P_{25}N_{50}K_{25}$ and 50%ww$P_0N_0K_0$. Root dry weight also increased up to the last stage of sampling.

**4.3.1.6 Root Diameter:** 100%ww significantly enhanced it at 40 DAS, while at later two stages 50%ww increased it up to 56.24% and 19.83% respectively proving the effectivity of dilution (Table 36). Among the phosphorus doses, $P_{50}$ at 40 and 70 DAS proved best while at 55 DAS, $P_{25}$ was the best. At 40 DAS, 100%ww$P_{25}N_{50}K_{25}$ gave the maximum root diameter and it was also at par with 100%ww$P_{50}N_{50}K_{25}$, while the last treatment was similar in effect with 50%ww$P_{12.5}N_{50}K_{25}$. At 55 DAS, lower concentration of wastewater and phosphorus (50%ww$P_{25}N_{50}K_{25}$) showed the maximum diameter and was statistically similar with 50%ww$P_{12.5}N_{50}K_{25}$. At 70 DAS, comparatively higher dose of P with lower concentration of wastewater (50%ww$P_{50}N_{50}K_{25}$) was statistically similar with 50%ww$P_{25}N_{50}K_{25}$ and 100%ww$P_{50}N_{50}K_{25}$ where the last treatment was equal to 50%ww$P_{12.5}N_{50}K_{25}$. 50%ww$P_{50}N_{50}K_{25}$ proving to be the maximum, remaining concentrations was more or less equal in their effect. Root diameter also increased up to the last stage of growth.

**Table: 35 Effect of 50%ww and 100%ww on root fresh weight (g $plant^{-1}$), root dry weight (g $plant^{-1}$) of turnip (*Brassica rapa*) under different levels of phosphorus.**

| | Root fresh weight | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | *wastewater* | | | *wastewater* | | | *wastewater* | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $P_0$ | 2.71 | 3.60 | 3.16 | 8.63 | 8.95 | 8.79 | 20.5 | 25.2 | 22.84 |
| $P_{12.5}$ | 3.91 | 3.38 | 3.65 | 20.3 | 9.00 | 14.7 | 34.6 | 24.5 | 29.52 |
| $P_{25}$ | 3.14 | 3.61 | 3.38 | 22.0 | 10.0 | 16.0 | 48.7 | 24.0 | 36.33 |
| $P_{50}$ | 5.03 | 3.48 | 4.26 | 17.7 | 11.7 | 14.7 | 46.8 | 46.8 | 46.78 |
| Mean | 3.70 | 3.52 | | 17.16 | 9.91 | | 37.63 | 30.11 | |

| **C.D. at 5%** | **40** | **55** | **70** |
|---|---|---|---|
| Water | 0.154 | 0.648 | 1.512 |
| Treatment | 0.218 | 0.917 | 2.139 |
| Interaction | 0.308 | 1.297 | 3.025 |

| | Root dry weight | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $P_0$ | 0.27 | 0.28 | 0.28 | 0.68 | 1.29 | 0.99 | 1.84 | 2.40 | 2.12 |
| $P_{12.5}$ | 0.37 | 0.26 | 0.32 | 2.52 | 0.75 | 1.64 | 2.83 | 2.11 | 2.47 |
| $P_{25}$ | 0.35 | 0.31 | 0.33 | 2.75 | 0.90 | 1.83 | 5.35 | 2.10 | 3.73 |
| $P_{50}$ | 0.41 | 0.31 | 0.36 | 2.29 | 0.98 | 1.64 | 4.31 | 4.93 | 4.62 |
| Mean | 0.35 | 0.29 | | 2.06 | 0.98 | | 3.58 | 2.89 | |

| **C.D. at 5%** | **40** | **55** | **70** |
|---|---|---|---|
| Water | 0.014 | 0.078 | 0.147 |
| Treatment | 0.020 | 0.110 | 0.207 |
| Interaction | 0.028 | 0.156 | 0.293 |

N.B: Subscript values denote the amount of phosphorus (P) in kg $ha^{-1}$. A uniform dose of nitrogen @ 50 kg $ha^{-1}$ ($N_{50}$) and of potassium @ 25 kg $ha^{-1}$ ($K_{25}$) was also applied basally. C.D: Critical Difference, DAS: Days After Sowing, WW: Wastewater.

**Table: 36 Effect of 50%ww and 100%ww on root diameter (cm), of turnip (*Brassica rapa*) under different levels of phosphorus.**

| | Root diameter | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $P_0$ | 0.74 | 1.06 | 0.87 | 1.28 | 1.60 | 1.44 | 3.10 | 3.20 | 3.15 |
| $P_{12.5}$ | 1.47 | 0.53 | 1.00 | 4.10 | 2.23 | 3.17 | 4.77 | 3.50 | 4.14 |
| $P_{25}$ | 0.70 | 1.60 | 1.15 | 4.33 | 2.27 | 3.30 | 5.23 | 3.50 | 4.37 |
| $P_{50}$ | 1.33 | 1.53 | 1.43 | 3.93 | 2.63 | 3.28 | 5.27 | 5.13 | 5.20 |
| Mean | 1.06 | 1.17 | | 3.41 | 2.18 | | 4.59 | 3.83 | |

| **C.D. at 5%** | **40** | **55** | **70** |
|---|---|---|---|
| Water | 0.050 | 0.134 | 0.184 |
| Treatment | 0.071 | 0.190 | 0.260 |
| Interaction | 0.102 | 0.268 | 0.368 |

N.B: Subscript values denote the amount of phosphorus (P) in kg $ha^{-1}$. A uniform dose of nitrogen @ 50 kg $ha^{-1}$ ($N_{50}$) and of potassium @ 25 kg $ha^{-1}$ ($K_{25}$) was also applied basally. C.D: Critical Difference, DAS: Days After Sowing, WW: Wastewater.

**4.3.1.7 Leaf Fresh Weight:** Contrary to some earlier observations, 100%ww proved good at 40 DAS, while at 55 and 70 DAS, 50%ww was better and gave an increase of 84.82% and 32.76% (Table 37). $P_{12.5}$ proved optimum for enhancing leaf fresh weight and gave an increase of 64.03% and 62.13% over $P_0$ at 40 and 70 DAS, while at 55 DAS, $P_{25}$ was optimum and gave an increase of 113.69%. At 40 DAS, interaction between wastewater and fertilizer was optimum in 50%ww$P_{12.5}N_{50}K_{25}$ showing an increase of 106.41% over 50%ww$P_0N_0K_0$ followed by 100%ww$P_{25}N_{50}K_{25}$, 100%ww$P_{50}N_{50}K_{25}$ and 50%ww$P_{25}N_{50}K_{25}$. At 55 DAS, 50%ww$P_{25}N_{50}K_{25}$ gave the maximum leaf fresh weight followed by 50%ww$P_{12.5}N_{50}K_{25}$, 50%ww$P_{50}N_{50}K_{25}$ and 100%ww$P_{12.5}N_{50}K_{25}$ the last treatment was at par with 100%ww$P_{25}N_{50}K_{25}$. 100%ww$P_0N_0K_0$ was at par with 50%ww$P_0N_0K_0$ indicating that 50%ww was better. While at 70 DAS, 50%ww$P_{12.5}N_{50}K_{25}$ showed the maximum leaf fresh weight followed by 50%ww$P_{25}N_{50}K_{25}$ and 100%ww$P_{25}N_{50}K_{25}$, the last treatment was at par with 100%ww$P_{12.5}N_{50}K_{25}$. Leaf fresh weight generally increased with the increase in plant growth.

**4.3.1.8 Leaf Dry Weight:** It was also responded to waste water, thus 50%ww proved best and showed an increase of 47.7% and 33.26% over 100%ww at the last two stages (Table 37). Among the fertilizer doses, $P_{12.5}$ proved best at 40 and 70 DAS. While at 55 DAS, $P_{25}$ was good giving an increase of 133.6%, and all the doses were critically different. At 40 DAS, interaction effect was maximum in 50%ww$P_{12.5}N_{50}K_{25}$ followed by 100%ww$P_{25}N_{50}K_{25}$ and 100%ww$P_{50}N_{50}K_{25}$ the later treatment was also at par with 50%ww$P_{25}N_{50}K_{25}$ and 100%ww$P_{12.5}N_{50}K_{25}$. The combination 50%ww$P_{50}N_{50}K_{25}$ was the least effective. At 55 DAS, 50%ww$P_{25}N_{50}K_{25}$ gave the maximum dry weight followed by100%ww$P_{25}N_{50}K_{25}$ and 50%ww$P_{50}N_{50}K_{25}$. Last treatment was also at par with 50%ww$P_{12.5}N_{50}K_{25}$ and 100%ww$P_{12.5}N_{50}K_{25}$ which in turn was equal to 50%ww$P_0N_0K_0$. At the last stage, 50%ww$P_{12.5}N_{50}K_{25}$ gave the maximum value giving 92.59% more dry weight over 50%$P_0N_0K_0$. The former treatment was followed by 50%ww$P_{25}N_{50}K_{25}$, 100%ww$P_{50}N_{50}K_{25}$ and 50%ww$P_{50}N_{50}K_{25}$.

**4.3.1.9 Leaf Number:** At 40 DAS, 100%ww proved best, while at 55 and 70 DAS, lower concentration was better and registered an increase of 19.33%and 7.55%. Among the phosphorus doses, at 40 and 70 DAS, $P_{25}$ was optimum (Table 38).

Similarly at 70 DAS, again $P_{25}$ showed the maximum leaf production thus proving to be optimum. Interaction was significant at all the samplings. Thus, at 40 DAS, 100%ww$P_{25}N_{50}K_{25}$ recorded the maximum leaf number giving an increase of 44.5% and it was critically different with other treatments. It was followed by 50%ww$P_{12.5}N_{50}K_{25}$. On one hand 100%ww$P_{12.5}N_{50}K_{25}$ was at par with 50%ww$P_{25}N_{50}K_{25}$, while on the other with 50%ww$P_0N_0K_0$, 50%ww$P_{50}N_{50}K_{25}$ and 100%ww$P_{50}N_{50}K_{25}$. At 55 DAS, 50%ww$P_{25}N_{50}K_{25}$ produced maximum leaves where an increase of 69.87% over 50%ww$P_0N_0K_0$ was observed. 50%ww$P_{50}N_{50}K_{25}$ was at par with 50%ww$P_{12.5}N_{50}K_{25}$ and 100%ww$P_0N_0K_0$ which in turn was equal to 100%ww$P_{25}N_{50}K_{25}$ and 100%ww$P_{12.5}N_{50}K_{25}$. At 70 DAS, again 50%ww$P_{25}N_{50}K_{25}$ recorded the maximum leaf production and it was also statistically equal with 50%ww$P_{50}N_{50}K_{25}$ and. 100%ww$P_0N_0K_0$ showing the economy of phosphatic fertilizer (25kg P) and also the importance of dilution for the effective use of waste water.

### 4.3.2 *Heavy metal content in root and leaf of turnip*

**4.3.2.1 Cadmium:** Its concentration generally decreased with increase in growth of the plant in case of root. While in leaf its concentration decreased with growth up to 55 DAS, and increased towards harvest. Concentration generally increased with increase in phosphorus doses also. Cd concentration was more in root then the leaf. 100%ww showed maximum Cd in root at all the three stages. Among the phosphorus doses comparatively lower dose ($P_{12.5}$) at 40 and 70 DAS, gave higher Cd content while at 55 DAS, $P_{25}$ accumulated more Cd (Table 39). At 40 DAS, the interaction 100%ww$P_{12.5}N_{50}K_{25}$ showed maximum concentration which was different with others. It was followed by 50%ww$P_{25}N_{50}K_{25}$, 50%ww$P_{12.5}N_{50}K_{25}$ and 50%ww$P_{50}N_{50}K_{25}$. Last treatment was at par with 100%ww$P_{50}N_{50}K_{25}$, 50%ww$P_0N_0K_0$, and 100%ww$P_0N_0K_0$. At 55 DAS, 100%ww$P_{25}N_{50}K_{25}$ was statistically different with the other treatments and gave the maximum Cd content. Similarly at 70 DAS, also 100%ww$P_{12.5}N_{50}K_{25}$ accumulated more and it was at par with 100%ww$P_{25}N_{50}K_{25}$. In case of leaf, 50%ww enhanced the concentration throughout the growth. Among the phosphorus doses, $P_{50}$ showed maximum Cd at 40 and 70 DAS while at 55 DAS, $P_{12.5}$ had more. Among interactions at 40 DAS, *100%ww$P_{50}N_{50}K_{25}$ registered* maximum concentration in leaf and this interaction was critically different with others. 50%ww$P_{50}N_{50}K_{25}$ gave more Cd at 55 DAS, and it was at par with

**Table: 37 Effect of 50%ww and 100%ww on leaf fresh weight (g plant$^{-1}$), leaf dry weight (g plant$^{-1}$) of turnip (*Brassica rapa*) under different levels of phosphorus.**

**Leaf fresh Weight**

| | Sampling days (DAS) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $P_0$ | 13.27 | 12.89 | 13.08 | 20.08 | 20.32 | 20.20 | 37.22 | 34.10 | 35.66 |
| $P_{12.5}$ | 27.39 | 15.52 | 21.46 | 36.34 | 24.00 | 30.17 | 76.41 | 39.22 | 57.82 |
| $P_{25}$ | 15.61 | 24.72 | 20.17 | 63.01 | 23.33 | 43.17 | 57.63 | 43.37 | 50.5 |
| $P_{50}$ | 12.77 | 18.25 | 15.51 | 33.33 | 15.01 | 24.17 | 33.92 | 37.86 | 35.89 |
| Mean | 17.26 | 17.85 | | 38.19 | 20.66 | | 51.30 | 38.64 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 0.540 | 1.455 | 2.119 |
| Treatment | 0.764 | 2.058 | 2.997 |
| Interaction | 1.081 | 2.911 | 4.239 |

**Leaf dry weight**

| | Sampling days (DAS) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $P_0$ | 1.31 | 1.40 | 1.36 | 2.27 | 1.45 | 1.86 | 3.24 | 2.36 | 2.80 |
| $P_{12.5}$ | 2.79 | 1.53 | 2.16 | 2.57 | 2.45 | 2.51 | 6.24 | 3.45 | 4.85 |
| $P_{25}$ | 1.53 | 2.12 | 1.83 | 5.64 | 3.05 | 4.35 | 4.54 | 3.43 | 3.99 |
| $P_{50}$ | 1.03 | 1.57 | 1.30 | 2.68 | 1.96 | 2.32 | 3.45 | 3.87 | 3.66 |
| Mean | 1.67 | 1.66 | | 3.29 | 2.23 | | 4.37 | 3.28 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | NS | 0.130 | 0.178 |
| Treatment | 0.110 | 0.184 | 0.252 |
| Interaction | 0.155 | 0.261 | 0.356 |

N.B: Subscript values denote the amount of phosphorus (P) in kg ha$^{-1}$. A uniform dose of nitrogen @ 50 kg ha$^{-1}$ ($N_{50}$) and of potassium @ 25 kg ha$^{-1}$ ($K_{25}$) was also applied basally. C.D: Critical Difference, N.S: Non Significant, DAS: Days After Sowing, WW: Wastewater.

**Table: 38 Effect of 50%ww and 100%ww on leaf number (plant$^{-1}$), of turnip (*Brassica rapa*) under different levels of phosphorus.**

| | Leaf number | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $P_0$ | 6.00 | 7.67 | 6.84 | 6.67 | 8.01 | 7.34 | 8.00 | 8.00 | 8.00 |
| $P_{12.5}$ | 8.00 | 5.67 | 6.84 | 8.33 | 7.33 | 7.83 | 8.00 | 7.67 | 7.84 |
| $P_{25}$ | 5.33 | 8.67 | 7.01 | 11.3 | 7.33 | 9.33 | 8.33 | 7.00 | 7.67 |
| $P_{50}$ | 6.00 | 5.67 | 5.84 | 8.67 | 6.67 | 7.67 | 8.30 | 7.67 | 7.99 |
| Mean | 6.33 | 6.92 | | 8.75 | 7.33 | | 8.16 | 7.59 | |

| **C.D. at 5%** | **40** | **55** | **70** |
|---|---|---|---|
| Water | 0.286 | 0.347 | 0.165 |
| Treatment | 0.404 | 0.491 | 0.234 |
| Interaction | 0.571 | 0.695 | 0.330 |

N.B: Subscript values denote the amount of phosphorus (P) in kg ha$^{-1}$. A uniform dose of nitrogen @ 50 kg ha$^{-1}$ ($N_{50}$) and of potassium @ 25 kg ha$^{-1}$ ($K_{25}$) was also applied basally. . C.D: Critical Difference, DAS: Days After Sowing, WW: Wastewater.

$50\%wwP_{12.5}N_{50}K_{25}$. While at 70 DAS, also the same treatment accumulated maximum Cd was equaled by $50\%wwP_{25}N_{50}K_{25}$.

**4.3.2.2 Chromium:** Its concentration was generally more in leaf at 40 and 55 DAS, while at harvest stage more in root. In case of root it was increased in 50%ww with increase of P doses. In root, Cr concentration generally decreased with growth of the plant but in case of leaf not much difference was found with growth at earlier two stages. In root, 50%ww recorded more Cr at early stage while at later two stages, 100%ww gave the maximum concentration (Table 40). Among the fertilizer doses higher concentration at 55 and 70 DAS, was given under lower concentration of P. At 40 DAS, the interaction, $100\%wwP_0N_0K_0$ accumulated more Cr content which was critically different with other treatments. It was followed by $50\%wwP_{50}N_{50}K_{25}$, $50\%wwP_{12.5}N_{50}K_{25}$ and $50\%wwP_{25}N_{50}K_{25}$. At later stage another interaction $100\%wwP_{12.5}N_{50}K_{25}$ showed higher concentration and it also differed with other treatments, followed by $100\%wwP_{25}N_{50}K_{25}$, $100\%wwP_{50}N_{50}K_{25}$ and $50\%wwP_0N_0K_0$. While at last stage again like earlier stage, $100\%wwP_{12.5}N_{50}K_{25}$ gave the maximum value. It was followed by $50\%wwP_{25}N_{50}K_{25}$, $50\%wwP_{50}N_{50}K_{25}$, $100\%wwP_{50}N_{50}K_{25}$ and $50\%wwP_{12.5}N_{50}K_{25}$. In case of leaf also, 50%ww showed maximum Cr at 55 DAS. Phosphorus dose $P_{12.5}$ gave more Cr and was statistically similar with $P_{50}$ at 40 DAS. Among the interactions $100\%wwP_{12.5}N_{50}K_{25}$ accumulated maximum Cr content as it was statistically similar with $50\%wwP_{50}N_{50}K_{25}$. It was followed by $50\%wwP_{25}N_{50}K_{25}$, $50\%wwP_{12.5}N_{50}K_{25}$ and $100\%wwP_{50}N_{50}K_{25}$. While at 55 DAS, diluted wastewater ($50\%wwP_{25}N_{50}K_{25}$) accumulated more. It was followed by $50\%wwP_{12.5}N_{50}K_{25}$ and $50\%wwP_{50}N_{50}K_{25}$. Last treatment was at par with $100\%wwP_{50}N_{50}K_{25}$ which in turn was at par with $100\%wwP_{12.5}N_{50}K_{25}$. Surprisingly at 70 DAS, Cr was not detected in any of the treatments.

**4.3.2.3 Nickel:** In general it was more in root at 40 and 70 DAS, while at 55 DAS, its concentration was more in leaf. In case of root its concentration first decreased with growth and again increased at harvest. While in case of leaf first increase with growth up to 55 DAS, and then decreased at harvest. In case of root its concentration generally increased with increase of P doses. But in case of leaf decrease with increase of P dose at 40 DAS, but at later two stages generally increased with increase

**Table: 39 Effect of 50%ww and 100%ww on Cadmium (mg/kg DW) in root and leaf of turnip (*Brassica rapa*) under different levels of phosphorus.**

| | Cadmium in root | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $P_0$ | 5.75 | 5.50 | 5.63 | 3.00 | 3.25 | 3.13 | 2.25 | 2.23 | 2.24 |
| $P_{12.5}$ | 7.08 | 13.0 | 10.0 | 7.78 | 3.53 | 5.65 | 2.68 | 3.63 | 3.15 |
| $P_{25}$ | 8.45 | 3.63 | 6.04 | 3.33 | 13.3 | 8.32 | 1.98 | 3.63 | 2.80 |
| $P_{50}$ | 6.13 | 5.75 | 5.94 | 8.88 | 5.08 | 6.98 | 2.25 | 2.48 | 2.36 |
| Mean | 6.85 | 6.98 | | 5.75 | 6.29 | | 2.29 | 2.99 | |

| **C.D. at 5%** | **40** | **55** | **70** |
|---|---|---|---|
| Water | 0.360 | 0.338 | 0.115 |
| Treatment | 0.509 | 0.477 | 0.162 |
| Interaction | 0.719 | 0.675 | 0.229 |

| | Cadmium in leaf | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | Wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $P_0$ | 3.75 | 3.25 | 3.50 | 1.25 | 1.25 | 1.25 | 2.50 | 2.50 | 2.50 |
| $P_{12.5}$ | 4.00 | 3.75 | 3.88 | 2.25 | 2.00 | 2.13 | 3.00 | 3.25 | 3.13 |
| $P_{25}$ | 4.50 | 3.75 | 4.13 | 1.50 | 1.50 | 1.50 | 3.75 | 2.75 | 3.25 |
| $P_{50}$ | 4.75 | 5.25 | 5.00 | 2.25 | 1.00 | 1.63 | 3.75 | 3.00 | 3.38 |
| Mean | 4.25 | 4.00 | | 1.81 | 1.44 | | 3.25 | 2.88 | |

| **C.D. at 5%** | **40** | **55** | **70** |
|---|---|---|---|
| Water | 0.174 | 0.075 | 0.131 |
| Treatment | 0.246 | 0.105 | 0.185 |
| Interaction | 0.348 | 0.149 | 0.262 |

N.B: Subscript values denote the amount of phosphorus (P) in kg $ha^{-1}$. A uniform dose of nitrogen @ 50 kg $ha^{-1}$ ($N_{50}$) and of potassium @ 25 kg $ha^{-1}$ ($K_{25}$) was also applied basally. C.D: Critical Difference, DW: Dry Weight, DAS: Days After Sowing, WW: Wastewater.

**Table: 40 Effect of 50%ww and 100%ww on Chromium (mg/kg DW) in root and leaf of turnip (*Brassica rapa*) under different levels of phosphorus.**

| | Chromium in root | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $P_0$ | 1.50 | N.D. | 0.75 | 11.5 | 6.50 | 9.0 | 8.50 | 5.5 | 7.0 |
| $P_{12.5}$ | 5.50 | N.D. | 2.75 | 6.00 | 43.2 | 24.6 | 9.40 | 28.2 | 18.8 |
| $P_{25}$ | 4.50 | N.D. | 2.25 | 9.50 | 29.5 | 19.5 | 10.8 | 8.25 | 9.53 |
| $P_{50}$ | 6.00 | N.D. | 3.00 | 10.6 | 23.9 | 17.2 | 10.2 | 9.60 | 9.88 |
| Mean | 4.38 | | | 9.40 | 25.74 | | 9.71 | 12.88 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 0.184 | 0.903 | 0.564 |
| Treatment | 0.261 | 1.278 | 0.798 |
| Interaction | 0.369 | 1.807 | 1.129 |

| | Chromium in leaf | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $P_0$ | 10.5 | 15.0 | 12.8 | 14.5 | 16.0 | 15.3 | N.D. | N.D. | N.D. |
| $P_{12.5}$ | 30.0 | 49.5 | 39.8 | 36.0 | 20.5 | 28.3 | N.D. | N.D. | N.D. |
| $P_{25}$ | 42.0 | 15.0 | 28.5 | 41.5 | 16.5 | 29.0 | N.D. | N.D. | N.D. |
| $P_{50}$ | 49.0 | 27.5 | 38.3 | 23.0 | 21.5 | 22.3 | N.D. | N.D. | N.D. |
| Mean | 32.88 | 26.8 | | 28.75 | 18.63 | | N.D. | N.D. | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 1.449 | 1.137 | NS |
| Treatment | 2.049 | 1.608 | NS |
| Interaction | 2.898 | 2.274 | NS |

N.B: Subscript values denote the amount of phosphorus (P) in kg $ha^{-1}$. A uniform dose of nitrogen @ 50 kg $ha^{-1}$ ($N_{50}$) and of potassium @ 25 kg $ha^{-1}$ ($K_{25}$) was also applied basally. C.D: Critical Difference, DW: Dry Weight, N.D: Not Detectable, DAS: Days After Sowing, WW: Wastewater.

of P dose was observed. In case of root, 100%ww showed maximum concentration at 40 and 70 DAS, while at 55 DAS, 50%ww gave more value. Among the phosphorus doses at 40 DAS, higher P dose ($P_{50}$) showed maximum Ni content while at 70 DAS, $P_{12.5}$ accumulated more Ni content. Among the interactions 100%ww$P_{50}N_{50}K_{25}$ recorded more Ni as it was different with other interactions (Table 41). It was followed by 100%ww$P_{25}N_{50}K_{25}$, 50%ww$P_{12.5}N_{50}K_{25}$, 50%ww$P_{25}N_{50}K_{25}$, 50%ww$P_{50}N_{50}K_{25}$ and 100%ww$P_{12.5}N_{50}K_{25}$. At 70 DAS, 50%ww$P_{12.5}N_{50}K_{25}$, gave maximum Ni content and was different with others. It was followed by 100%ww$P_{25}N_{50}K_{25}$, 50%ww$P_{25}N_{50}K_{25}$, 100%ww$P_{12.5}N_{50}K_{25}$, 100%ww$P_{50}N_{50}K_{25}$ and 100%ww$P_0N_0K_0$. In case of leaf, 100%ww at 40 and 70 DAS, gave the maximum values while at 55 DAS, 50%ww accumulated more. Among the phosphorus doses, $P_{12.5}$ at 40 and 70 DAS, and $P_{25}$ at 55 DAS, showed maximum content. The interaction 100%ww$P_{12.5}N_{50}K_{25}$ gave the maximum Ni concentration at 40 DAS, and had similar effect with 50%ww$P_{12.5}N_{50}K_{25}$. While at 55 DAS, 50%ww$P_{25}N_{50}K_{25}$ accumulated more. It was equally effective with 50%ww$P_{50}N_{50}K_{25}$ and last treatment was at par with 100%ww$P_{12.5}N_{50}K_{25}$. At 70 DAS, 50%ww$P_{12.5}N_{50}K_{25}$ had more Ni content and was different with other interactions followed by 100%ww$P_{25}N_{50}K_{25}$ and 100%ww$P_{12.5}N_{50}K_{25}$. Last treatment was at par with 50%ww$P_{25}N_{50}K_{25}$.

**4.3.2.4 Iron:** It was more in leaf then in root and in case of leaf, Fe content decreased with growth of the plant. While in root it decreased up to 55 DAS, and increased at harvest. In roots, 50%ww showed more Fe content at three stages. Among the phosphorus doses, $P_{12.5}$ at 40 and 70 DAS, while at 55 DAS, $P_{50}$ gave higher iron content (Table 42). Among the interactions, 50%ww$P_{12.5}N_{50}K_{25}$ accumulated more iron. It was critically different with other interactions followed by 100%ww$P_{50}N_{50}K_{25}$. At later stage, 50%ww$P_{12.5}N_{50}K_{25}$ showed maximum Fe content and gave equal effect with 100%ww$P_{25}N_{50}K_{25}$ and 100%ww$P_{50}N_{50}K_{25}$. At last stage, 50%ww$P_{12.5}N_{50}K_{25}$ accumulated more Fe in root while in case of leaf at 40 DAS, 100%ww and 50%ww at 55 and 70 DAS, accumulated more iron. Fertilizer dose, $P_{12.5}$ at 40 DAS, $P_{25}$ at 55 DAS, and $P_{50}$ at harvest proved more effective. The interaction at 40 DAS, was maximum in 100%ww$P_{12.5}N_{50}K_{25}$ and also different with other interactions. It was followed by 50%ww$P_{25}N_{50}K_{25}$ and 50%ww$P_{12.5}N_{50}K_{25}$. At second stage, 50%ww$P_{25}N_{50}K_{25}$ accumulated more iron followed by 100%ww$P_{25}N_{50}K_{25}$, and 50%ww$P_{12.5}N_{50}K_{25}$. At 70 DAS, 50%ww$P_{12.5}N_{50}K_{25}$ gave the maximum value and

**Table: 41 Effect of 50%ww and 100%ww on Nickel (mg/kg DW) in root and leaf of turnip (*Brassica rapa*) under different levels of phosphorus.**

| Nickel in root | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $P_0$ | 42.0 | 68.0 | 55.0 | 40.0 | 47.0 | 43.5 | 45.0 | 52.0 | 48.5 |
| $P_{12.5}$ | 81.7 | 73.1 | 77.4 | 32.7 | 24.8 | 28.8 | 76.6 | 58.4 | 67.5 |
| $P_{25}$ | 78.5 | 86.4 | 82.5 | 31.3 | 20.9 | 26.1 | 61.7 | 68.9 | 65.3 |
| $P_{50}$ | 73.1 | 106.0 | 89.6 | 27.1 | 31.8 | 29.5 | 38.0 | 53.9 | 46.0 |
| Mean | 68.83 | 83.38 | | 32.78 | 31.13 | | 55.33 | 58.3 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 3.28 | 1.37 | 2.53 |
| Treatment | 4.64 | 1.93 | 3.58 |
| Interaction | 6.57 | 2.73 | 5.06 |

| Nickel in leaf | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $P_0$ | 10.0 | 19.0 | 14.5 | 45.0 | 41.0 | 43.0 | 30.0 | 37.0 | 33.5 |
| $P_{12.5}$ | 59.8 | 61.3 | 60.6 | 110.0 | 119.0 | 114.5 | 59.0 | 49.0 | 54.0 |
| $P_{25}$ | 17.0 | 29.0 | 23.0 | 131.0 | 106.0 | 118.5 | 49.0 | 53.0 | 51.0 |
| $P_{50}$ | 9.00 | 1.00 | 5.0 | 127.0 | 110.0 | 118.5 | 33.0 | 40.0 | 36.5 |
| Mean | 23.95 | 27.58 | | 103.25 | 94.0 | | 42.75 | 44.75 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 1.557 | 4.529 | 1.963 |
| Treatment | 2.202 | 6.405 | 2.776 |
| Interaction | 3.114 | 9.058 | 3.926 |

N.B: Subscript values denote the amount of phosphorus (P) in kg $ha^{-1}$. A uniform dose of nitrogen @ 50 kg $ha^{-1}$ ($N_{50}$) and of potassium @ 25 kg $ha^{-1}$ ($K_{25}$) was also applied basally. C.D: Critical Difference, DW: Dry Weight, DAS: Days After Sowing, WW: Wastewater.

was statistically similar with $50\%wwP_{50}N_{50}K_{25}$, $100\%wwP_{50}N_{50}K_{25}$ and $100\%wwP_{25}N_{50}K_{25}$ and the last treatment was also at par with $100\%wwP_{12.5}N_{50}K_{25}$.

**4.3.2.5 Copper:** In general Cu was more in leaf at 40 and 55 DAS, while at 70 DAS, it was more in root. Its concentration in leaf was generally decreased with growth while in case of root it generally increased with growth. In root, 100%ww showed maximum Cu content at 55 DAS, while at 40 and 70 DAS, 50%ww surpassed it (Table 43). $P_{12.5}$ at 70 DAS, gave more value while at 55 DAS, higher P dose ($P_{50}$) showed maximum Cu content. Among the interactions, $100\%wwP_{12.5}N_{50}K_{25}$ giving higher concentration as it was statistically different with other treatments followed by $100\%wwP_{25}N_{50}K_{25}$, $50\%wwP_{12.5}N_{50}K_{25}$ and $100\%wwP_0N_0K_0$. At second stage, $100\%wwP_{50}N_{50}K_{25}$, recorded maximum Cu content followed by $100\%wwP_{12.5}N_{50}K_{25}$, which in turn was at par with $100\%wwP_{25}N_{50}K_{25}$. While at harvest, $50\%wwP_{12.5}N_{50}K_{25}$, accumulated more followed by $50\%wwP_{25}N_{50}K_{25}$, which was also statistically equal to $50\%wwP_{50}N_{50}K_{25}$, followed by $100\%wwP_{12.5}N_{50}K_{25}$, $100\%wwP_{25}N_{50}K_{25}$, and $100\%wwP_{50}N_{50}K_{25}$. In case of leaf at 40 and 70 DAS, 50%ww gave the maximum Cu while at second stage, 100%ww accumulated more. Out of P doses, $P_{12.5}$ accumulated maximum and among interactions, $100\%wwP_0N_0K_0$ and it was followed by $50\%wwP_{50}N_{50}K_{25}$, $50\%wwP_{12.5}N_{50}K_{25}$, $50\%wwP_{25}N_{50}K_{25}$ and $100\%wwP_{12.5}N_{50}K_{25}$. At 55 DAS, $100\%wwP_{12.5}N_{50}K_{25}$ accumulated more and was equally effective with $100\%wwP_{50}N_{50}K_{25}$, $50\%wwP_{12.5}N_{50}K_{25}$ and $100\%wwP_{25}N_{50}K_{25}$. While at the last stage, $50\%wwP_{50}N_{50}K_{25}$ had more Cu and it was also similar to $50\%wwP_{12.5}N_{50}K_{25}$.

**4.3.2.6 Manganese:** This heavy metal was more in leaf then in root. Specific trend was not observed for increase of Mn content with increase of P doses in both organs. Its concentration was generally decreased with growth. In root at 40 and 70 DAS, 50%ww recorded more Mn while at 55 DAS, 100%ww gave higher value. Among the phosphorus doses at 40 and 55 DAS, $P_{50}$ gave the maximum content while at 70 DAS, $P_{12.5}$ recorded more (Table 44). At 40 DAS, among the wastewater and phosphorus doses $100\%wwP_{50}N_{50}K_{25}$ showed maximum Mn content followed by $50\%wwP_{50}N_{50}K_{25}$ and it was at par with $50\%wwP_{12.5}N_{50}K_{25}$ which was followed by $50\%wwP_{25}N_{50}K_{25}$, $100\%wwP_{25}N_{50}K_{25}$ and $50\%wwP_0N_0K_0$. While at 55 DAS, $100\%wwP_{50}N_{50}K_{25}$ accumulated more and followed by $50\%wwP_{50}N_{50}K_{25}$ and the last

**Table: 42 Effect of 50%ww and 100%ww on Iron (mg/kg DW) in root and leaf of turnip (*Brassica rapa*) under different levels of phosphorus.**

**Iron in root**

| | Sampling days (DAS) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $P_0$ | 651.0 | 463.0 | 557.0 | 435.0 | 265.0 | 350.0 | 450.0 | 325.0 | 387.5 |
| $P_{12.5}$ | 833.6 | 500.0 | 666.8 | 485.0 | 320.0 | 402.5 | 550.0 | 413.9 | 482.0 |
| $P_{25}$ | 389.5 | 599.0 | 494.3 | 329.5 | 472.0 | 400.8 | 411.0 | 447.0 | 429.0 |
| $P_{50}$ | 462.0 | 713.0 | 587.5 | 353.0 | 462.0 | 407.5 | 550.0 | 305.0 | 427.5 |
| Mean | 584.0 | 568.8 | | 400.6 | 379.8 | | 490.3 | 372.7 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 14.69 | 16.98 | 19.05 |
| Treatment | 20.78 | 24.01 | 26.94 |
| Interaction | 29.39 | 33.96 | 38.10 |

**Iron in leaf**

| | Sampling days (DAS) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $P_0$ | 812.0 | 850.0 | 831.0 | 525.0 | 483.0 | 504.0 | 495.0 | 445.0 | 470.0 |
| $P_{12.5}$ | 1103.0 | 1251.0 | 1177.0 | 956.0 | 505.0 | 730.5 | 552.0 | 508.0 | 530.0 |
| $P_{25}$ | 1164.0 | 1059.0 | 1111.5 | 1117.0 | 1108.0 | 1112.5 | 504.0 | 534.0 | 519.0 |
| $P_{50}$ | 946.0 | 946.0 | 946.0 | 835.0 | 913.0 | 874.0 | 545.0 | 541.0 | 543.0 |
| Mean | 1006.3 | 1026.5 | | 858.3 | 752.3 | | 524.0 | 507.0 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 17.57 | 36.43 | 14.52 |
| Treatment | 24.85 | 51.52 | 20.54 |
| Interaction | 35.14 | 72.85 | 29.04 |

N.B: Subscript values denote the amount of phosphorus (P) in kg ha$^{-1}$. A uniform dose of nitrogen @ 50 kg ha$^{-1}$ ($N_{50}$) and of potassium @ 25 kg ha$^{-1}$ ($K_{25}$) was also applied basally. C.D: Critical Difference, DW: Dry Weight, DAS: Days After Sowing, WW: Wastewater.

treatment was at par with 50%ww$P_0N_0K_0$. At 70 DAS, 50%ww$P_{50}N_{50}K_{25}$ accumulated higher Mn content and it was equally effective with 50%ww$P_{12.5}N_{50}K_{25}$, 100%ww$P_{12.5}N_{50}K_{25}$, 100%ww$P_{25}N_{50}K_{25}$ and 50%ww$P_{25}N_{50}K_{25}$. In case of leaf at 40 and 55 DAS, 100%ww gave higher Mn content in leaf while at 70 DAS, 50%ww accumulated maximum Mn. Among the phosphorus doses, $P_{25}$ registered more than the other doses. The interactive effect was maximum in 50%ww$P_{25}N_{50}K_{25}$ and was at par with 100%ww$P_0N_0K_0$. Last treatment was at par with 100%ww$P_{12.5}N_{50}K_{25}$. At 55 DAS, 100%ww$P_{25}N_{50}K_{25}$ accumulated more Mn and was statistically similar with 100%ww$P_{50}N_{50}K_{25}$ and 50%ww$P_{25}N_{50}K_{25}$ while at 70 DAS, 50%ww$P_0N_0K_0$ registered higher value although at par with 50%ww$P_{25}N_{50}K_{25}$.

**4.3.2.7 Zinc:** The concentration of Zn was more in leaf then root at second stage of sampling. Its concentration in leaf increased first then decreased with growth. While in root it was generally decreased with growth. At 40 and 55 DAS, 100%ww showed higher Zn content while at 70 DAS, 50%ww had more Zn in root. $P_{12.5}$ showed more Zn over $P_0$ at 40 and 70 DAS, (Table 45). At 40 DAS, interaction 100%ww$P_{12.5}N_{50}K_{25}$ accumulated maximum Zn content and was different with other combinations followed by 100%ww$P_{50}N_{50}K_{25}$. At later stage, 100%ww$P_{50}N_{50}K_{25}$ gave more Zn and was followed by 100%ww$P_{12.5}N_{50}K_{25}$ and the last treatment was also at par with 100%ww$P_{25}N_{50}K_{25}$ and 100%ww$P_0N_0K_0$. At 70 DAS, 100%ww$P_{12.5}N_{50}K_{25}$ accumulated more and had equal effect with 50%ww$P_{25}N_{50}K_{25}$ and 50%ww$P_{12.5}N_{50}K_{25}$. In case of leaf, wastewater effect was found to be non significant at 40DAS, while at 55 and 70 DAS, it was significant. At 55 DAS, 100%ww whereas, at 70 DAS, 50%ww accumulated more Zn content. $P_{50}$ at 40 DAS, where as $P_{12.5}$ at 55 and 70 DAS, enhanced it. At 55 DAS, 100%ww$P_{50}N_{50}K_{25}$, gave higher value and it was equally effective with 50%ww$P_{12.5}N_{50}K_{25}$, 100%ww$P_{12.5}N_{50}K_{25}$, 100%ww$P_{25}N_{50}K_{25}$ and 100%ww$P_0N_0K_0$. At 70DAS, 50%ww$P_{50}N_{50}K_{25}$ accumulated more and was equally effective with 50%ww$P_{12.5}N_{50}K_{25}$ and 100%ww$P_{12.5}N_{50}K_{25}$.

**Table: 43 Effect of 50%ww and 100%ww on Copper (mg/kg DW) in root and leaf of turnip (*Brassica rapa*) under different levels of phosphorus.**

| Copper in root | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $P_0$ | 4.50 | 2.50 | 3.50 | 2.00 | 7.50 | 4.75 | 3.50 | 2.00 | 2.75 |
| $P_{12.5}$ | 3.50 | 12.5 | 8.00 | 2.20 | 16.8 | 9.48 | 24.4 | 17.5 | 20.95 |
| $P_{25}$ | 1.75 | 4.35 | 3.05 | 2.45 | 16.6 | 9.50 | 20.2 | 15.2 | 17.68 |
| $P_{50}$ | 2.00 | 1.65 | 1.83 | 6.70 | 22.2 | 14.5 | 19.4 | 14.7 | 17.03 |
| Mean | 2.94 | 5.25 | | 3.34 | 15.8 | | 16.86 | 12.34 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 0.402 | 0.483 | 0.746 |
| Treatment | 0.568 | 0.683 | 1.055 |
| Interaction | 0.804 | 0.965 | 1.492 |

| Copper in leaf | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $P_0$ | 9.30 | 12.1 | 10.7 | 5.00 | 10.0 | 7.50 | 1.00 | 0.50 | 0.75 |
| $P_{12.5}$ | 10.5 | 10.1 | 10.3 | 12.4 | 13.1 | 12.8 | 3.05 | 0.95 | 2.00 |
| $P_{25}$ | 10.2 | 5.10 | 7.63 | 9.15 | 12.4 | 10.8 | 2.85 | 0.40 | 1.63 |
| $P_{50}$ | 10.9 | 9.05 | 9.95 | 6.65 | 12.5 | 9.55 | 3.20 | 0.45 | 1.83 |
| Mean | 10.19 | 9.09 | | 8.30 | 11.98 | | 2.53 | 0.58 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 0.416 | 0.453 | 0.090 |
| Treatment | 0.588 | 0.640 | 0.127 |
| Interaction | 0.831 | 0.905 | 0.180 |

N.B: Subscript values denote the amount of phosphorus (P) in kg $ha^{-1}$. A uniform dose of nitrogen @ 50 kg $ha^{-1}$ ($N_{50}$) and of potassium @ 25 kg $ha^{-1}$ ($K_{25}$) was also applied basally. C.D: Critical Difference. DW: Dry Weight, DAS: Days After Sowing, WW: Wastewater.

**Table: 44 Effect of 50%ww and 100%ww on Manganese (mg/kg DW) in root and leaf of turnip (*Brassica rapa*) under different levels of phosphorus.**

| | **Manganese in root** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | Wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $P_0$ | 61.3 | 31.0 | 46.15 | 61.0 | 42.9 | 51.95 | 41.2 | 29.8 | 35.50 |
| $P_{12.5}$ | 73.9 | 33.2 | 53.55 | 44.9 | 44.9 | 44.9 | 48.6 | 47.9 | 48.25 |
| $P_{25}$ | 66.8 | 66.5 | 66.65 | 39.3 | 45.8 | 42.55 | 45.9 | 46.2 | 46.05 |
| $P_{50}$ | 78.7 | 95.4 | 87.05 | 61.8 | 90.5 | 76.15 | 48.6 | 39.6 | 44.10 |
| Mean | 70.18 | 56.53 | | 51.75 | 56.03 | | 46.08 | 40.88 | |

| **C.D. at 5%** | **40** | **55** | **70** |
|---|---|---|---|
| Water | 2.823 | 2.269 | 1.883 |
| Treatment | 3.993 | 3.209 | 2.663 |
| Interaction | 5.647 | 4.539 | 3.766 |

| | **Manganese in leaf** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $P_0$ | 86.3 | 98.0 | 92.15 | 80.9 | 78.5 | 79.7 | 98.7 | 61.4 | 80.05 |
| $P_{12.5}$ | 88.3 | 96.4 | 92.35 | 98.8 | 100.7 | 99.8 | 62.6 | 79.1 | 70.85 |
| $P_{25}$ | 99.4 | 92.9 | 96.15 | 112.5 | 113.8 | 113.2 | 95.5 | 91.5 | 93.50 |
| $P_{50}$ | 94.0 | 85.3 | 89.65 | 107.8 | 112.6 | 110.2 | 80.5 | 79.7 | 80.10 |
| Mean | 92.0 | 93.15 | | 100.0 | 101.4 | | 84.33 | 77.93 | |

| **C.D. at 5%** | **40** | **55** | **70** |
|---|---|---|---|
| Water | 1.105 | 1.313 | 3.384 |
| Treatment | 1.563 | 1.856 | 4.785 |
| Interaction | 2.210 | 2.625 | 6.768 |

N.B: Subscript values denote the amount of phosphorus (P) in kg $ha^{-1}$. A uniform dose of nitrogen @ 50 kg $ha^{-1}$ ($N_{50}$) and of potassium @ 25 kg $ha^{-1}$ ($K_{25}$) was also applied basally. C.D: Critical Difference, DW: Dry Weight, DAS: Days After Sowing, WW: Wastewater.

**Table: 45 Effect of 50%ww and 100%ww on Zinc (mg/kg DW) in root and leaf of turnip (*Brassica rapa*) under different levels of phosphorus.**

| Zinc in root | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $P_0$ | 85.0 | 93.0 | 89.0 | 70.0 | 82.0 | 76.0 | 75.0 | 72.0 | 73.5 |
| $P_{12.5}$ | 82.0 | 147.0 | 114.5 | 51.0 | 84.0 | 67.5 | 85.7 | 86.9 | 86.3 |
| $P_{25}$ | 86.0 | 87.0 | 86.5 | 60.0 | 82.0 | 71.0 | 86.5 | 75.5 | 81.0 |
| $P_{50}$ | 93.0 | 100.0 | 96.5 | 62.0 | 90.0 | 76.0 | 77.3 | 65.4 | 71.4 |
| Mean | 86.5 | 106.8 | | 60.75 | 84.5 | | 81.13 | 74.95 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 4.105 | 2.953 | 3.347 |
| Treatment | 5.805 | 4.176 | 4.733 |
| Interaction | 8.210 | 5.906 | 6.694 |

| Zinc in leaf | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $P_0$ | 81.3 | 82.0 | 81.7 | 91.0 | 98.0 | 94.5 | 82.9 | 68.4 | 75.7 |
| $P_{12.5}$ | 90.5 | 96.1 | 93.3 | 102.0 | 99.3 | 100.7 | 89.5 | 87.5 | 88.5 |
| $P_{25}$ | 90.5 | 84.7 | 87.6 | 95.4 | 99.0 | 97.2 | 84.3 | 74.0 | 79.2 |
| $P_{50}$ | 95.1 | 95.1 | 95.1 | 90.7 | 103.2 | 96.95 | 91.6 | 70.9 | 81.3 |
| Mean | 89.35 | 89.48 | | 94.78 | 99.88 | | 87.08 | 75.2 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | NS | 2.726 | 3.480 |
| Treatment | 5.319 | 3.855 | 4.921 |
| Interaction | NS | 5.452 | 6.960 |

N.B: Subscript values denote the amount of phosphorus (P) in kg $ha^{-1}$. A uniform dose of nitrogen @ 50 kg $ha^{-1}$ ($N_{50}$) and of potassium @ 25 kg $ha^{-1}$ ($K_{25}$) was also applied basally. C.D: Critical Difference, DW: Dry Weight, DAS: Days After Sowing, WW: Wastewater.

## 4.4 EXPERIMENT- IV

### 4.4.1 *Growth and yield characteristics*

**4.4.1.1 Plant Fresh Weight:** At 55 and 70 DAS, 50%ww and at 40 DAS, 100%ww proved beneficial in enhancing the plant fresh weight, giving 3.68% and 15.81% more values respectively (Table 46). Among the fertilizer doses, $K_{12.5}$ was more effective showing an increase of 65.77%, 50.66% and 84.98% over $K_0$. At 40 DAS, interaction 50%ww$K_{12.5}N_{50}P_{25}$ performed better giving maximum growth and yield with an increase of 101.68% and it was followed by 100%$K_{12.5}N_{50}P_{25}$, 100%$K_{25}N_{50}P_{25}$ and 100%ww$K_0N_0P_0$. Last treatment was at par with 50%ww$K_{25}N_{50}P_{25}$ and 100%$K_{50}N_{50}P_{25}$. At the following stage again, 50%ww$K_{12.5}N_{50}P_{25}$ proved good registering an increase of 95.3% more fresh weight. It was followed by 100%$K_{12.5}N_{50}P_{25}$ which was at par with 50%ww$K_{50}N_{50}P_{25}$. Similarly the interactions, 50%ww$K_{25}N_{50}P_{25}$, 100%ww$K_0N_0P_0$, were equally effective and the same was the case with 100%$K_{25}N_{50}P_{25}$ and 100%$K_{50}N_{50}P_{25}$. While at the last stage, 50%ww$K_{25}N_{50}P_{25}$ was at par with 50%ww$K_{12.5}N_{50}P_{25}$, gave an increase of 102.02% over 50%ww$K_0N_0P_0$. The combination 50%ww$K_{50}N_{50}P_{25}$ was equal to 100%$K_{25}N_{50}P_{25}$ in its effect. An increasing trend was observed in the plant fresh weight up to the last stage of sampling.

**4.4.1.2 Plant Dry Weight:** Effect of wastewater was non significant at 40 DAS, whereas at 55 and 70 DAS, lower concentration, 50%ww, proved beneficial in enhancing 7.83% and 26.61% more dry weight (Table 46). Among fertilizer doses, $K_{12.5}$ proved best at 40 and 70 DAS, showing an increase of 57.7% and 70.77% over $K_0$. Whereas at 55 DAS, $K_{50}$ gave the maximum value giving 59.4% more. The interaction effect was significant at 40 DAS, where lower concentration of wastewater and fertilizer dose 50%ww$K_{12.5}N_{50}P_{25}$ showed maximum dry weight by increasing 70.98% more than 50%ww$K_0N_0P_0$ followed by 100%ww$K_{12.5}N_{50}P_{25}$. Last treatment was equal to 100%ww$K_{25}N_{50}P_{25}$. Similarly 50%ww$K_{25}N_{50}P_{25}$ was equally effective with 100%ww$K_{50}N_{50}P_{25}$, 50%ww$K_{50}N_{50}P_{25}$, 50%ww$K_0N_0P_0$ and 100%ww$K_0N_0P_0$. At 55 DAS, 50%ww$K_{50}N_{50}P_{25}$ comparatively higher fertilizer dose gave more dry weight followed by 50%ww$K_{12.5}N_{50}P_{25}$ which in turn was at par with100%ww$K_{12.5}N_{50}P_{25}$. On the one hand the 100%ww$K_{25}N_{50}P_{25}$ was at par with100%ww$K_{50}N_{50}P_{25}$, while on the other with 50%ww$K_{25}N_{50}P_{25}$. At 70 DAS, like plant fresh weight,

$50\%wwK_{25}N_{50}P_{25}$, was equal with $50\%wwK_{12.5}N_{50}P_{25}$ giving the 79.17% increase. It was followed by $50\%wwK_{50}N_{50}P_{25}$ which in turn was at par with $100\%wwK_{12.5}N_{50}P_{25}$. Similarly the interaction $50\%wwK_0N_0P_0$ was at par with $100\%wwK_0N_0P_0$ as well as with $100\%wwK_{50}N_{50}P_{25}$. Like fresh weight, an increasing trend was observed in the plant dry weight up to the last stage of sampling.

**4.4.1.3 Plant Height:** 100%ww was better than 50%ww giving an increase of 10.94%, 7.36% and 4.31% (Table 47). While among the potassium doses, $K_{12.5}$ proved best showing an increase of 11.21%, 3.62% and 6.59% over $K_0$. Interactive effect of waste water and fertilizer was also significant. Therefore, at 40 DAS, $100\%wwK_{12.5}N_{50}P_{25}$ gave the maximum plant height giving an increase of 25.07% over $50\%wwK_0N_0P_0$ and had similar effect with $100\%wwK_0N_0P_0$, $50\%wwK_{12.5}N_{50}P_{25}$ and $100\%wwK_{25}N_{50}P_{25}$. At later stage, $50\%wwK_{12.5}N_{50}P_{25}$ was better by showing an increase of 7.50% and was statistically equal with $100\%wwK_0N_0P_0$, $100\%wwK_{12.5}N_{50}P_{25}$ and $100\%wwK_{25}N_{50}P_{25}$. While at the last stage, again $100\%wwK_{12.5}N_{50}P_{25}$ gave an increase of 7.39% and it was at par with $50\%wwK_0N_0P_0$.

**4.4.1.4 Root Fresh Weight:** 100% concentration of wastewater proved good at 40 and 55 DAS, while at 70 DAS, 50%ww enhanced more root growth (Table 48). $K_{12.5}$, proved best as it increased 33.43% and 83.35% weight over $K_0$ at the last two stages of sampling. At 40 DAS, unexpectedly $50\%wwK_0N_0P_0$ was better while at 55 DAS, $100\%wwK_{12.5}N_{50}P_{25}$ recorded maximum root fresh weight and it showed an increase of 90.98% over $50\%wwK_0N_0P_0$. It was followed by $100\%wwK_0N_0P_0$. The last treatment was at par with $50\%wwK_{12.5}N_{50}P_{25}$, and $100\%K_{50}N_{50}P_{25}$ which in turn was equaled by $50\%wwK_{50}N_{50}P_{25}$. While at 70 DAS, again $50\%wwK_{12.5}N_{50}P_{25}$, may be treated as optimum giving an increase of 63.13% more root fresh weight over $50\%wwK_0N_0P_0$ which was statistically equal with $50\%wwK_{25}N_{50}P_{25}$. Like plant fresh weight, root fresh weight also consistently increased up to the last stage of sampling.

**4.4.1.5 Root Dry Weight:** At 40 and 55 DAS, 100%ww was good between the two wastewater treatments and showed an increase of 34.92% and 20.20% while at 70 DAS, diluted wastewater was better. $K_{12.5}$, the lower dose of potassium, proved best as it showed an increase of 57.79% and 87.01% respectively over $K_0$ (Table 48). At 40 DAS, $50\%wwK_0N_0P_0$ was comparatively better while at 55 DAS, $100\%wwK_{12.5}N_{50}P_{25}$ recorded the maximum root dry weight and it was different with

**Table: 46 Effect of 50%ww and 100%ww on plant fresh weight (g plant$^{-1}$), plant dry weight (g plant$^{-1}$) of turnip (*Brassica rapa*) under different levels of potassium.**

**Plant fresh weight**

| | Sampling days (DAS) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $K_0$ | 19.7 | 25.0 | 22.3 | 32.8 | 48.7 | 40.7 | 67.2 | 69.6 | 68.4 |
| $K_{12.5}$ | 39.7 | 34.3 | 37.0 | 64.0 | 58.7 | 61.3 | 133.7 | 119.3 | 126.5 |
| $K_{25}$ | 24.0 | 28.3 | 26.2 | 48.8 | 45.7 | 47.2 | 135.7 | 104.0 | 119.9 |
| $K_{50}$ | 20.0 | 24.0 | 22.0 | 58.3 | 43.7 | 51.0 | 105.0 | 88.3 | 96.7 |
| Mean | 25.84 | 27.91 | | 50.98 | 49.17 | | 110.39 | 95.32 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 1.22 | 1.47 | 4.65 |
| Treatment | 1.73 | 2.08 | 6.58 |
| Interaction | 2.44 | 2.95 | 9.30 |

**Plant dry weight**

| | Sampling days (DAS) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $K_0$ | 1.93 | 1.90 | 1.92 | 3.20 | 3.77 | 3.49 | 6.53 | 5.99 | 6.26 |
| $K_{12.5}$ | 3.30 | 2.74 | 3.02 | 5.68 | 5.40 | 5.54 | 11.4 | 9.94 | 10.69 |
| $K_{25}$ | 2.10 | 2.68 | 2.39 | 4.20 | 4.32 | 4.26 | 11.7 | 8.31 | 10.01 |
| $K_{50}$ | 1.98 | 2.05 | 2.02 | 6.47 | 4.64 | 5.56 | 9.96 | 7.06 | 8.51 |
| **Mean** | **2.33** | **2.34** | | **4.89** | **4.53** | | **9.91** | **7.83** | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | NS | 0.208 | 0.400 |
| Treatment | 0.148 | 0.294 | 0.566 |
| Interaction | 0.210 | 0.415 | 0.801 |

N.B: Subscript values denote the amount of potassium (K) in kg ha$^{-1}$. A uniform dose of nitrogen @ 50 kg ha$^{-1}$ ($N_{50}$) and of potassium @ 25 kg ha$^{-1}$ ($P_{25}$) was also applied basally. C.D: Critical Difference, DAS: Days After Sowing, WW: Wastewater.

**Table: 47 Effect of 50%ww and 100%ww on plant height (cm $plant^{-1}$), of turnip (*Brassica rapa*) under different levels of potassium.**

| | Plant height | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $K_0$ | 29.0 | 35.5 | 32.3 | 34.0 | 36.5 | 35.3 | 40.2 | 36.0 | 38.1 |
| $K_{12.5}$ | 35.5 | 35.8 | 35.7 | 36.5 | 36.5 | 36.5 | 38.0 | 43.0 | 40.5 |
| $K_{25}$ | 32.5 | 35.0 | 33.8 | 32.8 | 35.8 | 34.3 | 34.0 | 38.2 | 36.1 |
| $K_{50}$ | 27.5 | 31.3 | 29.4 | 28.8 | 32.8 | 30.8 | 36.2 | 37.0 | 36.6 |
| Mean | 31.1 | 34.4 | | 33.0 | 35.4 | | 37.1 | 38.8 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 1.547 | 1.380 | 1.629 |
| Treatment | 1.774 | 1.538 | 1.889 |
| Interaction | 2.094 | 1.761 | 2.257 |

N.B: Subscript values denote the amount of potassium (K) in kg $ha^{-1}$. A uniform dose of nitrogen @ 50 kg $ha^{-1}$ ($N_{50}$) and of potassium @ 25 kg $ha^{-1}$ ($P_{25}$) was also applied basally. C.D: Critical Difference, DAS: Days After Sowing, WW: Wastewater.

other treatments followed by 50%ww$K_{50}N_{50}P_{25}$. At 70 DAS, 50%ww$K_{25}N_{50}P_{25}$ was at par with 50%ww$K_{12.5}N_{50}P_{25}$, and it was followed by 50%ww$K_{50}N_{50}P_{25}$.

**4.4.1.6 Root Diameter:** At early stage higher concentration was more effective giving an increase of 42.86% over lower concentration. Among the K doses, $K_{12.5}$, as in most of the observed values, proved good for root diameter at 40 and 70 DAS, whereas at 55 DAS, higher potassium ($K_{50}$) dose showed the maximum root diameter followed by $K_{12.5}$ and $K_{25}$ (Table 49). At 40 DAS, comparatively lower dose combination 100%ww$K_{12.5}N_{50}P_{25}$ proved better and had similar effect with 100%ww$K_{50}N_{50}P_{25}$ followed by 100%ww$K_{25}N_{50}P_{25}$ and 50%ww$K_{12.5}N_{50}P_{25}$. Last treatment was at par with 50%ww$K_{25}N_{50}P_{25}$. At 55 DAS, 50%ww$K_{50}N_{50}P_{25}$ gave more root diameter and had similar effect with 100%ww$K_{50}N_{50}P_{25}$. Last treatment was at par with 100%ww$K_{12.5}N_{50}P_{25}$ and 50%ww$K_{12.5}N_{50}P_{25}$ while it was at par with 100%ww$K_{25}N_{50}P_{25}$ and 50%ww$K_{25}N_{50}P_{25}$. At 70 DAS, interestingly lower concentration of water and lower doses of fertilizer 50%ww$K_{12.5}N_{50}P_{25}$ showed the maximum root diameter and it was at par with 50%ww$K_{25}N_{50}P_{25}$ followed by 100%ww$K_{12.5}N_{50}P_{25}$. Like plant fresh weight, root diameter also consistently increased up to the last stage of sampling.

**4.4.1.7 Leaf Fresh Weight:** Leaf in turnip crop is an important part as it is commonly eaten up as green vegetable in India (Table 50). At 40 and 70DAS, 100%ww increased leaf production by 2.77% and 39.68% over 50%ww. While at 55 DAS, 50%ww was more effective giving an increase of 16.15% over 100%ww. Among the potassium doses, again lower dose $K_{12.5}$ proved best at all the sampling stages giving an increase of 108.39%, 61.54% and 87.96% over $K_0$. Among the interactions at 40 DAS, the optimum combination was 50%ww$K_{12.5}N_{50}P_{25}$, followed by 100%ww$K_{12.5}N_{50}P_{25}$, 100%ww$K_{25}N_{50}P_{25}$, 50%ww$K_{25}N_{50}P_{25}$ and 50%ww$K_{50}N_{50}P_{25}$ and the last treatment was at par with 100%ww$K_0N_0P_0$ and 100%ww$K_{50}N_{50}P_{25}$. At second sampling again, 50%ww$K_{12.5}N_{50}P_{25}$ proved good followed by 50%ww$K_{50}N_{50}P_{25}$ and 50%ww$K_{25}N_{50}P_{25}$. At last stage however, higher concentration of wastewater was more effective 100%ww$K_{12.5}N_{50}P_{25}$, followed by 100%ww$K_{25}N_{50}P_{25}$, and 50%ww$K_{12.5}N_{50}P_{25}$, and the latter treatment was equal to 50%ww$K_{25}N_{50}P_{25}$. Like plant fresh weight, leaf fresh weight also increased up to the last stage of sampling.

**Table: 48 Effect of 50%ww and 100%ww on root fresh weight (g plant$^{-1}$), root dry weight (g plant$^{-1}$) of turnip (*Brassica rapa*) under different levels of potassium.**

| | Root fresh weight | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | Wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $K_0$ | 6.75 | 6.20 | 6.48 | 12.4 | 19.1 | 15.75 | 56.6 | 31.9 | 44.3 |
| $K_{12.5}$ | 3.50 | 4.46 | 3.98 | 18.3 | 23.7 | 21.02 | 92.3 | 70.0 | 81.2 |
| $K_{25}$ | 2.51 | 3.44 | 2.98 | 13.0 | 12.3 | 12.67 | 94.6 | 59.0 | 76.8 |
| $K_{50}$ | 1.15 | 5.62 | 3.39 | 16.7 | 18.0 | 17.34 | 79.0 | 54.0 | 66.5 |
| Mean | 3.48 | 4.93 | | 15.10 | 18.28 | | 80.62 | 53.74 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 0.187 | 0.725 | 3.11 |
| Treatment | 0.264 | 1.025 | 4.40 |
| Interaction | 0.373 | 1.450 | 6.23 |

| | Root dry weight | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $K_0$ | 0.64 | 0.49 | 0.57 | 0.97 | 1.66 | 1.32 | 4.45 | 2.40 | 3.43 |
| $K_{12.5}$ | 0.31 | 0.45 | 0.38 | 1.71 | 2.44 | 2.08 | 7.27 | 5.54 | 6.41 |
| $K_{25}$ | 0.19 | 0.33 | 0.26 | 1.24 | 1.12 | 1.18 | 7.49 | 4.50 | 6.00 |
| $K_{50}$ | 0.12 | 0.43 | 0.28 | 2.04 | 1.98 | 2.03 | 5.72 | 4.10 | 4.91 |
| Mean | 0.315 | 0.425 | | 1.498 | 1.80 | | 6.23 | 4.14 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 0.017 | 0.073 | 0.242 |
| Treatment | 0.023 | 0.103 | 0.342 |
| Interaction | 0.033 | 0.145 | 0.483 |

N.B: Subscript values denote the amount of potassium (K) in kg ha$^{-1}$. A uniform dose of nitrogen @ 50 kg ha$^{-1}$ ($N_{50}$) and of potassium @ 25 kg ha$^{-1}$ ($P_{25}$) was also applied basally. C.D: Critical Difference. DAS: Days After Sowing, WW: Wastewater.

**Table: 49 Effect of 50%ww and 100%ww on root diameter (cm), of turnip (*Brassica rapa*) under different levels of potassium.**

| | Root diameter | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $K_0$ | 0.74 | 1.0 | 0.87 | 1.28 | 1.60 | 1.44 | 3.10 | 1.50 | 2.30 |
| $K_{12.5}$ | 1.30 | 1.80 | 1.55 | 3.10 | 3.17 | 3.14 | 7.17 | 6.0 | 6.59 |
| $K_{25}$ | 1.30 | 1.43 | 1.37 | 3.03 | 3.03 | 3.03 | 7.0 | 5.12 | 6.06 |
| $K_{50}$ | 0.93 | 1.87 | 1.40 | 3.53 | 3.30 | 3.42 | 5.63 | 5.27 | 5.45 |
| Mean | 1.07 | 1.53 | | 2.74 | 2.78 | | 5.73 | 4.47 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 0.057 | NS | 0.241 |
| Treatment | 0.081 | 0.175 | 0.341 |
| Interaction | 0.114 | 0.247 | 0.483 |

N.B: Subscript values denote the amount of potassium (K) in kg $ha^{-1}$. A uniform dose of nitrogen @ 50 kg $ha^{-1}$ ($N_{50}$) and of potassium @ 25 kg $ha^{-1}$ ($P_{25}$) was also applied basally. C.D: Critical Difference, DAS: Days After Sowing, WW: Wastewater.

**4.4.1.8 Leaf Dry Weight:** Diluted waste water (50%ww) gave maximum leaf dry weight giving an increase of 4.95% and 24.06% over 100%ww at earlier two stages (Table 50). $K_{12.5}$ was more effective at 40 and 70 DAS, giving an increase of 95.56% and 51.15%. While at 55 DAS, unexpectedly higher potassic dose ($K_{50}$) proved best followed by $K_{12.5}$. Among interactions at early stage, 50%ww$K_{12.5}N_{50}P_{25}$ improved this parameter more followed by 100%ww$K_{25}N_{50}P_{25}$. Last treatment was at par with 100%ww$K_{12.5}N_{50}P_{25}$ which in turn was followed by 50%ww$K_{25}N_{50}P_{25}$, 50%ww$K_{50}N_{50}P_{25}$, 100%ww$K_{50}N_{50}P_{25}$ and 100%ww$K_0N_0P_0$. While at 55 DAS, 50%ww$K_{50}N_{50}P_{25}$ proved best among all the interactions and was statistically different with others followed by 50%ww$K_{12.5}N_{50}P_{25}$ and 100%ww$K_{25}N_{50}P_{25}$. At last sampling four combinations were generally effective. Thus 100%ww$K_{12.5}N_{50}P_{25}$ with 50%ww$K_{50}N_{50}P_{25}$, 50%ww$K_{25}N_{25}P_{25}$ and 50%ww$K_{12.5}N_{50}P_{25}$ by showing an increase of 111.54% more over 50%ww$K_0N_0P_0$.

**4.4.1.9 Leaf Number:** At earlier two stages, like most of growth parameters 50%ww proved best and the effect of wastewater was found to be significant while at harvest effect of wastewater was non significant (Table 51). Among K doses again $K_{12.5}$ proved more effective giving an increase of 12.76% and 9.07% over $K_0$ at earlier two stages. While at 70 DAS, $K_{25}$ showed the maximum leaf production giving an increase of 14.56%. Among the interactions at 40 DAS, 50%ww$K_{12.5}N_{50}P_{25}$ produced maximum leaves giving an increase of 25.0% over 50%ww$K_0N_0P_0$. It was followed by 100%ww$K_{50}N_{50}P_{25}$, 50%ww$K_0N_0P_0$, 100%ww$K_0N_0P_0$, 100%ww$K_{12.5}N_{50}P_{25}$ and 100%ww$K_{25}N_{50}P_{25}$. While at 55 DAS, again the same combination 50%ww$K_{12.5}N_{50}P_{25}$ proved better giving an increase of 49.93% more then 50%ww$K_0N_0P_0$, and it was statistically different with other treatments. It was followed by 50%ww$K_{50}N_{50}P_{25}$.

### 4.4.2 *Heavy metal content in root and leaf of turnip*

**4.4.2.1 Cadmium:** In root at 40 and 55 DAS, 50%ww showed maximum concentration while at 70 DAS, it was100%ww (Table 52). Among the potassium doses $K_{50}$ recorded more Cd content. At 40 DAS, 50%ww$K_{50}N_{50}P_{25}$ accumulated higher Cd content and it was critically different with other interactions, It was followed by 100%ww$K_{50}N_{50}P_{25}$, 100%ww$K_{25}N_{50}P_{25}$ and 100%ww$K_{12.5}N_{50}P_{25}$. At 55 DAS, 50%ww$K_{25}N_{50}P_{25}$ accumulated more and had similar effect with

**Table: 50 Effect of 50%ww and 100%ww on leaf fresh weight (g plant$^{-1}$), leaf dry weight (g plant$^{-1}$) of turnip (*Brassica rapa*) under different levels of potassium.**

| | Leaf fresh weight | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $K_0$ | 12.9 | 18.8 | 15.85 | 20.4 | 29.6 | 24.96 | 10.6 | 37.7 | 24.14 |
| $K_{12.5}$ | 36.2 | 29.9 | 33.02 | 45.7 | 35.0 | 40.32 | 41.4 | 49.3 | 45.37 |
| $K_{25}$ | 21.5 | 24.9 | 23.19 | 35.8 | 33.3 | 34.57 | 41.1 | 45.0 | 43.05 |
| $K_{50}$ | 18.9 | 18.4 | 18.62 | 41.7 | 25.7 | 33.67 | 26.0 | 34.3 | 30.17 |
| Mean | 22.36 | 22.98 | | 35.87 | 30.89 | | 29.77 | 41.59 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 0.531 | 1.50 | 1.62 |
| Treatment | 0.751 | 2.13 | 2.29 |
| Interaction | 1.061 | 3.01 | 3.23 |

| | Leaf dry weight | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $K_0$ | 1.29 | 1.41 | 1.35 | 2.23 | 2.11 | 2.17 | 2.04 | 3.59 | 2.84 |
| $K_{12.5}$ | 2.99 | 2.29 | 2.64 | 3.97 | 2.96 | 3.47 | 4.17 | 4.40 | 4.29 |
| $K_{25}$ | 1.91 | 2.35 | 2.13 | 2.96 | 3.20 | 3.08 | 4.21 | 3.81 | 4.01 |
| $K_{50}$ | 1.86 | 1.62 | 1.74 | 4.40 | 2.66 | 3.53 | 4.24 | 2.96 | 3.60 |
| Mean | 2.01 | 1.92 | | 3.39 | 2.73 | | 3.68 | 3.69 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 0.091 | 0.137 | NS |
| Treatment | 0.128 | 0.194 | 0.229 |
| Interaction | 0.181 | 0.274 | 0.323 |

N.B: Subscript values denote the amount of potassium (K) in kg ha$^{-1}$. A uniform dose of nitrogen @ 50 kg ha$^{-1}$ ($N_{50}$) and of potassium @ 25 kg ha$^{-1}$ ($P_{25}$) was also applied basally. C.D: Critical Difference, DAS: Days After Sowing, WW: Wastewater.

**Table: 51 Effect of 50%ww and 100%ww on leaf number (plant$^{-1}$), plant height (cm plant$^{-1}$) of turnip (*Brassica rapa*) under different levels of potassium.**

| Leaf number | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $K_0$ | 8.00 | 7.67 | 7.84 | 6.67 | 8.0 | 7.34 | 8.00 | 8.0 | 8.0 |
| $K_{12.5}$ | 10.0 | 7.67 | 8.84 | 10.0 | 6.0 | 8.00 | 8.33 | 9.0 | 8.67 |
| $K_{25}$ | 7.00 | 7.33 | 7.17 | 7.33 | 7.0 | 7.17 | 9.33 | 9.0 | 9.17 |
| $K_{50}$ | 5.33 | 8.00 | 6.67 | 9.00 | 6.33 | 7.67 | 8.00 | 7.33 | 7.67 |
| Mean | 7.58 | 7.67 | | 8.25 | 6.83 | | 8.42 | 8.33 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 0.067 | 0.330 | NS |
| Treatment | 0.094 | 0.467 | 0.50 |
| Interaction | 0.133 | 0.660 | NS |

N.B: Subscript values denote the amount of potassium (K) in kg ha$^{-1}$. A uniform dose of nitrogen @ 50 kg ha$^{-1}$ ($N_{50}$) and of potassium @ 25 kg ha$^{-1}$ ($P_{25}$) was also applied basally. C.D: Critical Difference. DAS: Days After Sowing, WW: Wastewater.

$50\%wwK_{50}N_{50}P_{25}$ followed by $50\%wwK_{12.5}N_{50}P_{25}$ and the last treatment had similar effect with $100\%wwK_{12.5}N_{50}P_{25}$, $100\%wwK_{50}N_{50}P_{25}$ and $50\%wwK_0N_0P_0$ while at 70 DAS, the combination $100\%wwK_{50}N_{50}P_{25}$ recorded maximum effect and it was followed by $50\%wwK_{12.5}N_{50}P_{25}$ and $100\%wwK_{25}N_{50}P_{25}$. In case of leaf, 50%ww gave more value. Among the K doses, $K_{12.5}$ at 40 and 55 DAS, while $K_{25}$ at 70 DAS, showed maximum heavy metal content over $K_0$. Among the interactions of wastewater and potassium, $50\%wwK_{12.5}N_{50}P_{25}$ accumulated higher Cd and was at par with $100\%wwK_{50}N_{50}P_{25}$. At 55 DAS, $50\%wwK_{12.5}N_{50}P_{25}$ had more and it was critically different with other treatments while at 70 DAS, $100\%wwK_{12.5}N_{50}P_{25}$ accumulated more Cd content and was equally effective with $50\%wwK_{25}N_{50}P_{25}$, $50\%wwK_{50}N_{50}P_{25}$ and the last treatments was at par with $50\%wwK_0N_0P_0$. Cd concentration was more in root at 40 and 55 DAS, while at 70 DAS, it was more or less similar in both organs. Its concentration generally increased with K doses in root as well as in leaf and generally decreased with growth.

**4.4.2.2Chromium:** It generally decreased with growth as well as with K dose in leaf. In root its concentration was more at 55 and 70 DAS, while at 40 DAS, its concentration was more in leaf than root. 50%ww showed maximum concentration at 55DAS, whereas at 70 DAS, 100%ww registered higher Cr content (Table 53). Among the fertilizer doses $K_{12.5}$ at 55 DAS, showed higher content and it was at par with $K_{25}$ while at 70 DAS, $K_{50}$ showed more and was at par with $K_{25}$. At 55 DAS, interaction $50\%wwK_{25}N_{50}P_{25}$ gave the maximum concentration followed by $50\%wwK_{12.5}N_{50}P_{25}$ and the last treatment was at par with $100\%wwK_{50}N_{50}P_{25}$. At 70 DAS, the combination $100\%wwK_{25}N_{50}P_{25}$ registered higher Cr content followed by $100\%wwK_{50}N_{50}P_{25}$ and $100\%wwK_{12.5}N_{50}P_{25}$. In case of leaf at 40 and 55 DAS, 100%ww gave higher values while at 70 DAS, 50%ww proved more effective. Among the potassium doses at 40 DAS, $K_{12.5}$ showed maximum Cr content and was at par with $K_{25}$ while at 55 DAS, it was $K_{25}$ while at 70 DAS, $K_{50}$. At 40 DAS, the combination $100\%wwK_{12.5}N_{50}P_{25}$ showed maximum Cr content in leaf which was statistically different with other treatments. While at 55 DAS, $100\%wwK_{25}N_{50}P_{25}$ showed maximum and was equally effective with $50\%wwK_{12.5}N_{50}P_{25}$. At 70 DAS, $50\%wwK_{50}N_{50}P_{25}$ had more Cr content and it was different with other treatments.

**Table: 52 Effect of 50%ww and 100%ww on Cadmium (mg/kg DW) in root and leaf of turnip (*Brassica rapa*) under different levels of potassium.**

| Cadmium in root | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | Wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $K_0$ | 5.50 | 6.75 | 6.13 | 2.70 | 1.95 | 2.33 | 2.55 | 2.38 | 2.47 |
| $K_{12.5}$ | 7.93 | 8.33 | 8.13 | 2.83 | 2.73 | 2.78 | 3.28 | 2.48 | 2.88 |
| $K_{25}$ | 6.33 | 10.1 | 8.23 | 3.13 | 2.10 | 2.61 | 2.45 | 2.98 | 2.71 |
| $K_{50}$ | 16.3 | 12.0 | 14.1 | 3.08 | 2.73 | 2.91 | 2.83 | 3.48 | 3.15 |
| Mean | 9.02 | 9.29 | | 2.93 | 2.38 | | 2.78 | 2.83 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 0.448 | 0.114 | 0.048 |
| Treatment | 0.634 | 0.162 | 0.068 |
| Interaction | 0.897 | 0.229 | 0.096 |

| Cadmium in leaf | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $K_0$ | 3.25 | 3.35 | 3.35 | 1.45 | 1.00 | 1.0 | 3.43 | 2.55 | 2.99 |
| $K_{12.5}$ | 4.68 | 3.53 | 4.10 | 2.65 | 1.25 | 1.25 | 2.93 | 3.37 | 3.33 |
| $K_{25}$ | 4.23 | 3.58 | 3.90 | 2.23 | 1.20 | 1.20 | 3.70 | 3.33 | 3.52 |
| $K_{50}$ | 3.53 | 4.35 | 3.95 | 1.55 | 1.45 | 1.45 | 3.55 | 2.95 | 3.25 |
| Mean | 3.93 | 3.73 | | 1.97 | 1.23 | | 3.40 | 3.14 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 0.165 | 0.076 | 0.138 |
| Treatment | 0.233 | 0.107 | 0.195 |
| Interaction | 0.330 | 0.151 | 0.276 |

N.B: Subscript values denote the amount of potassium (K) in kg $ha^{-1}$. A uniform dose of nitrogen @ 50 kg $ha^{-1}$ ($N_{50}$) and of potassium @ 25 kg $ha^{-1}$ ($P_{25}$) was also applied basally. C.D: Critical Difference. DW: Dry Weight, DAS: Days After Sowing, WW: Wastewater.

**Table: 53 Effect of 50%ww and 100%ww on Chromium (mg/kg DW) in root and leaf of turnip (*Brassica rapa*) under different levels of potassium.**

| | Chromium in root | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | Wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $K_0$ | N.D. | N.D. | N.D. | 15.0 | 11.0 | 13.0 | 2.5 | 5.0 | 3.75 |
| $K_{12.5}$ | N.D. | N.D. | N.D. | 40.9 | 37.6 | 39.3 | 7.45 | 9.30 | 8.38 |
| $K_{25}$ | N.D. | N.D. | N.D. | 44.3 | 33.3 | 38.8 | 6.95 | 12.25 | 9.60 |
| $K_{50}$ | N.D. | N.D. | N.D. | 31.7 | 40.8 | 36.3 | 9.00 | 10.95 | 9.98 |
| Mean | N.D. | N.D. | | 32.96 | 30.71 | | 6.48 | 9.38 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | NS | 1.492 | 0.357 |
| Treatment | NS | 2.109 | 0.505 |
| Interaction | NS | 2.901 | 0.714 |

| | Chromium in leaf | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | Wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $K_0$ | 9.80 | 22.9 | 16.35 | 7.00 | 6.00 | 6.50 | N.D. | N.D. | N.D. |
| $K_{12.5}$ | 16.9 | 43.0 | 29.95 | 19.7 | 14.2 | 16.93 | 0.25 | N.D. | 0.13 |
| $K_{25}$ | 23.0 | 36.0 | 29.45 | 17.2 | 20.9 | 19.00 | N.D. | N.D. | N.D. |
| $K_{50}$ | 12.9 | 23.1 | 17.98 | 10.6 | 18.0 | 14.25 | 3.35 | N.D. | 1.68 |
| Mean | 15.62 | 31.24 | | 13.6 | 14.74 | | 0.90 | N.D. | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 1.076 | 0.670 | 0.052 |
| Treatment | 1.521 | 0.948 | 0.074 |
| Interaction | 2.151 | 1.340 | 0.105 |

N.B: Subscript values denote the amount of potassium (K) in kg $ha^{-1}$. A uniform dose of nitrogen @ 50 kg $ha^{-1}$ ($N_{50}$) and of potassium @ 25 kg $ha^{-1}$ ($P_{25}$) was also applied basally. C.D: Critical Difference, DW: Dry Weight, N.S: Non Significant, N.D: Not Detectable, DAS: Days After Sowing, WW: Wastewater.

**4.4.2.3 Nickel:** The concentration of Ni generally increased with K doses in both leaf and root. Its concentration increased at 55 DAS, while decreased at harvest stage. Ni content was more in root at 40 and 70 DAS, while at 55 DAS, it was more in leaf. In case of root 50%ww showed higher concentration at all the three stages and among the K doses, $K_{50}$ at 40 DAS, while at 55 and 70 DAS, $K_{12.5}$ accumulated more (Table 54). In case of interactions at 40 DAS, 50%ww$K_{50}N_{50}P_{25}$ had maximum Ni which was critically different with other treatments and the last one was followed by 100%ww$K_{50}N_{50}P_{25}$, 50%ww$K_{12.5}N_{50}P_{25}$ and 100%ww$K_{12.5}N_{50}P_{25}$. At 55 DAS, the interaction 100%ww$K_{12.5}N_{50}P_{25}$ accumulated higher content and was statistically similar with 50%ww$K_{12.5}N_{50}P_{25}$. At 70 DAS, 50%ww$K_{12.5}N_{50}P_{25}$ proved more effective and was critically different with other treatments followed by 50%ww$K_{50}N_{50}P_{25}$ and 50%ww$K_{25}N_{50}P_{25}$. In case of leaf 100%ww accumulated maximum Ni content $K_{50}$ recorded more Ni at 40 and 70 DAS, while at 55 DAS, it was $K_{12.5}$. The combination 100%ww$K_{50}N_{50}P_{25}$ accumulated maximum Ni and was critically different with other interactions followed by 50%ww$K_{50}N_{50}P_{25}$. 50%ww$K_{25}N_{50}P_{25}$, 100%ww$K_{25}N_{50}P_{25}$ and 50%ww$K_0N_0P_0$. While at 55 DAS, 100%ww$K_{50}N_{50}P_{25}$ accumulated more and it was statistically at par with 100%ww$K_{12.5}N_{50}P_{25}$ and 100%ww$K_{25}N_{50}P_{25}$ and the last treatment was followed by 50%ww$K_{12.5}N_{50}P_{25}$, 50%ww$K_{25}N_{50}P_{25}$, 100%ww$K_0N_0P_0$ and 50%ww$K_{50}N_{50}P_{25}$. At 70 DAS, 100%ww$K_{50}N_{50}P_{25}$ proved more effective and it was followed by 50%ww$K_{50}N_{50}P_{25}$.

**4.4.2.4 Iron:** In root, Fe content decreased at second stage and again increased at harvest. While in case of leaf it generally decreased with growth. At 55 and 70 DAS, its concentration was more or less similar. Fe content was more in leaf than root (Table 55). Among the fertilizer doses at 40 DAS, $K_{50}$ showed maximum Fe content while at 70 DAS $K_{12.5}$ accumulated more. Among the interactions, 100%ww$K_{50}N_{50}P_{25}$ gave higher Fe content and it was critically different with other treatments. At second stage, 100%ww$K_0N_0P_0$ gave more Fe and it was statistically equal with 50%ww$K_{25}N_{50}P_{25}$, and last treatment was equaled by 50%ww$K_{50}N_{50}P_{25}$, and 100%ww$K_{12.5}N_{50}P_{25}$. While at 70 DAS, 50%ww$K_{12.5}N_{50}P_{25}$ accumulated maximum Fe and was equal in effect with 100%ww$K_{12.5}N_{50}P_{25}$ and 50%ww$K_0N_0P_0$. In case of leaf at 40 DAS, 100%ww proved effective while at 55 and 70DAS, 50%ww

**Table: 54 Effect of 50%ww and 100%ww on Nickel (mg/kg DW) in root and leaf of turnip (*Brassica rapa*) under different levels of potassium.**

**Nickel in root**

| | Sampling days (DAS) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $K_0$ | 60.0 | 68.0 | 64.0 | 20.0 | 18.0 | 19.0 | 63.0 | 37.6 | 50.3 |
| $K_{12.5}$ | 93.9 | 75.9 | 84.9 | 26.5 | 28.3 | 27.4 | 86.5 | 62.1 | 74.3 |
| $K_{25}$ | 71.0 | 71.7 | 71.4 | 22.1 | 16.6 | 19.4 | 69.9 | 37.9 | 53.9 |
| $K_{50}$ | 136.2 | 115.7 | 126.0 | 21.7 | 17.7 | 19.7 | 76.8 | 67.5 | 72.2 |
| Mean | 90.28 | 82.83 | | 22.58 | 20.15 | | 74.05 | 51.28 | |

| **C.D. at 5%** | **40** | **55** | **70** |
|---|---|---|---|
| Water | 3.792 | 0.946 | 2.844 |
| Treatment | 5.363 | 1.337 | 4.023 |
| Interaction | 7.584 | 1.891 | 5.689 |

**Nickel in leaf**

| | Sampling days (DAS) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $K_0$ | N.D. | N.D. | N.D. | 38.0 | 50.7 | 44.4 | 32.0 | 35.0 | 33.5 |
| $K_{12.5}$ | N.D. | N.D. | N.D. | 82.7 | 98.1 | 90.4 | 42.6 | 38.1 | 40.4 |
| $K_{25}$ | 8.10 | 2.00 | 5.10 | 62.2 | 93.7 | 78.0 | 40.5 | 37.5 | 39.0 |
| $K_{50}$ | 10.7 | 25.5 | 18.1 | 40.8 | 99.2 | 70.0 | 43.5 | 50.9 | 47.2 |
| Mean | 4.70 | 6.88 | | 55.93 | 85.43 | | 39.65 | 40.38 | |

| **C.D. at 5%** | **40** | **55** | **70** |
|---|---|---|---|
| Water | 0.429 | 3.217 | 0.679 |
| Treatment | 0.606 | 4.550 | 0.960 |
| Interaction | 0.858 | 6.435 | 1.358 |

N.B: Subscript values denote the amount of potassium (K) in kg $ha^{-1}$. A uniform dose of nitrogen @ 50 kg $ha^{-1}$ ($N_{50}$) and of potassium @ 25 kg $ha^{-1}$ ($P_{25}$) was also applied basally. C.D: Critical Difference, DW: Dry Weight, N.D: Not Detectable, DAS: Days After Sowing, WW: Wastewater.

registered higher Fe content. At 40 and 70 DAS, $K_{50}$ accumulated more while at 55 DAS, $K_{25}$ gave more in leaf. At 40 DAS, interaction 100%ww$K_{50}N_{50}P_{25}$ registered maximum Fe content and it was critically different with other combinations followed by 50%ww$K_{12.5}N_{50}P_{25}$, 100%ww$K_{12.5}N_{50}P_{25}$ and 100%ww$K_{25}N_{50}P_{25}$ and the last was at par with 50%ww$K_{25}N_{50}P_{25}$. 100%ww$K_0N_0P_0$ and 50%ww$K_{50}N_{50}P_{25}$. At second stage, 50%ww$K_{25}N_{50}P_{25}$ was critically different with the others and it was followed by 50%ww$K_{12.5}N_{50}P_{25}$, 100%ww$K_{25}N_{50}P_{25}$ and 50%ww$K_{50}N_{50}P_{25}$. While at 70 DAS, 50%ww$K_{50}N_{50}P_{25}$ accumulated more Fe. It differed with other interactions and followed by 100%ww$K_{12.5}N_{50}P_{25}$ which was statistically similar with 50%ww$K_{25}N_{50}P_{25}$, 50%ww$K_{12.5}N_{50}P_{25}$, 50%ww$K_0N_0P_0$ and 100%ww$K_{25}N_{50}P_{25}$.

**4.4.2.5 Copper:** In root, its concentration generally decreased with growth and at 40 and 70 DAS, generally decreased with K doses, while at 55 DAS, it increased in some cases. In case of leaf, its concentration decreased with growth. Concentration of Cu increased with K doses at 40 DAS, while at 55 DAS, it generally decreased. Cu concentration was more in root than leaf at 55 and 70 DAS. In root 50%ww at 40 DAS, while at 55 and 70 DAS, 100%ww showed maximum Cu content (Table 56). Among the potassium doses at 55 DAS, $K_{25}$ had more while at 40 and 70 DAS, it was in $K_{12.5}$. Among the interactions 50%ww$K_{12.5}N_{50}P_{25}$ accumulate maximum Cu content and followed by 50%ww$K_{25}N_{50}P_{25}$ and was critically different with the other treatments. At later stage, 50%ww$K_{25}N_{50}P_{25}$ proved more effective and it was critically different with other combinations followed by 50%ww$K_{12.5}N_{50}P_{25}$. Last combination was at par with 100%ww$K_{50}N_{50}P_{25}$. While at 70 DAS, 100%ww$K_{12.5}N_{50}P_{25}$ gave more Cu content. In case of leaf at 40 and 70 DAS, 100%ww accumulated higher Cu while at 55 DAS, it was 50%ww. Among the potassium doses $K_{50}$ accumulated maximum Cu content at 40 DAS, while at 55 and 70 DAS, it was $K_{12.5}$. Among the interactions 100%ww$K_{25}N_{50}P_{25}$ by giving an increase of 43.55% higher Cu content and was statistically similar with 100%ww$K_{50}N_{50}P_{25}$. Last treatment was at par with 100%ww$K_{12.5}N_{50}P_{25}$. At second stage, 50%ww$K_{12.5}N_{50}P_{25}$ registered more Cu in leaf and it was critically different with other followed by 50%ww$K_{50}N_{50}P_{25}$, 100%ww$K_{12.5}N_{50}P_{25}$ and 100%ww$K_{25}N_{50}P_{25}$. At 70 DAS, 100%ww$K_{12.5}N_{50}P_{25}$ accumulated maximum Cu content followed by 100%ww$K_{25}N_{50}P_{25}$, 100%ww$K_{50}N_{50}P_{25}$ and 100%ww$K_0N_0P_0$.

**Table: 55 Effect of 50%ww and 100%ww on Iron (mg/kg DW) in root and leaf of turnip (*Brassica rapa*) under different levels of potassium.**

| | Iron in root | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $K_0$ | 620.0 | 865.0 | 742.5 | 301.0 | 321.0 | 311.0 | 470.0 | 389.0 | 429.5 |
| $K_{12.5}$ | 590.7 | 785.0 | 687.9 | 282.7 | 301.3 | 292.0 | 501.3 | 496.7 | 499.0 |
| $K_{25}$ | 632.4 | 633.5 | 633.0 | 306.7 | 271.6 | 289.2 | 398.6 | 462.1 | 430.4 |
| $K_{50}$ | 818.0 | 1107.7 | 962.9 | 302.9 | 262.5 | 282.7 | 400.7 | 356.8 | 378.8 |
| Mean | 665.28 | 847.8 | | 298.33 | 289.1 | | 442.65 | 426.2 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 31.107 | 8.184 | 12.49 |
| Treatment | 43.992 | 11.57 | 17.67 |
| Interaction | 62.214 | 16.37 | 24.98 |

| | Iron in leaf | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $K_0$ | 783.0 | 975.0 | 879.0 | 495.0 | 483.0 | 489.0 | 650.0 | 445.0 | 547.5 |
| $K_{12.5}$ | 1093.0 | 1036.0 | 1064.5 | 697.0 | 475.0 | 586.0 | 667.0 | 686.0 | 676.5 |
| $K_{25}$ | 1001.0 | 1028.0 | 1014.5 | 777.0 | 633.0 | 705.0 | 683.0 | 638.0 | 660.5 |
| $K_{50}$ | 974.0 | 1197.0 | 1085.5 | 555.0 | 515.0 | 535.0 | 915.0 | 609.0 | 762.0 |
| Mean | 962.75 | 1059.0 | | 631.0 | 526.5 | | 728.8 | 594.5 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 42.83 | 25.42 | 28.48 |
| Treatment | 60.57 | 35.95 | 40.28 |
| Interaction | 85.65 | 50.84 | 56.97 |

N.B: Subscript values denote the amount of potassium (K) in kg $ha^{-1}$. A uniform dose of nitrogen @ 50 kg $ha^{-1}$ ($N_{50}$) and of potassium @ 25 kg $ha^{-1}$ ($P_{25}$) was also applied basally. C.D: Critical Difference. DW: Dry Weight, DAS: Days After Sowing, WW: Wastewater.

**4.4.2.6 Manganese:** At first stage, its concentration was more or less similar in root and leaf but at 55 and 70 DAS, it was more in leaf. Its concentration generally increased with K doses in root and leaf at 40 DAS, while at 55 and 70 DAS, it generally decreased in root. Mn concentration also decreased with growth while at 55 and 70 DAS, it was more or less similar in root. In leaf at 40 and 70 DAS, its content was more or less similar while at 55 DAS, it showed higher values. At 40 DAS, 50%ww while at 55 and 70 DAS, 100%ww accumulated higher Mn content in root (Table 57). At 40 DAS, $K_{50}$ gave higher content. While at 70 DAS, $K_{12.5}$ accumulated more. Among the interactions at 40 DAS, 50%ww$K_{50}N_{50}P_{25}$ had more Mn content and it was critically different with other combinations followed by 100%ww$K_{25}N_{50}P_{25}$ and 100%ww$K_{50}N_{50}P_{25}$. At 55 DAS, 100%ww$K_0N_0P_0$ registered more content and critically different with others followed by 50%ww$K_{50}N_{50}P_{25}$. At 70 DAS, 100%ww$K_0N_0P_0$ gave the maximum value and it was equally effective with 100%ww$K_{12.5}N_{50}P_{25}$, 100%ww$K_{25}N_{50}P_{25}$. Last treatment was at par with 50%ww$K_{12.5}N_{50}P_{25}$ which in turn was at par with 50%ww$K_{25}$ $N_{50}P_{25}$ and 100%ww$K_{50}N_{50}P_{25}$. In case of leaf, 50%ww gave more Mn content by giving an increase over 100%ww at all the sampling stages. Among the potassium doses at 40 DAS, $K_{50}$ recorded higher Mn content which was equally effective with $K_{25}$. At 55 DAS, $K_{12.5}$ was equal to $K_{25}$, in effect of Mn accumulation. While at 70 DAS, $K_{25}$ accumulated higher Mn and was equally effective with $K_{50}$. Among the interactions, 50%ww$K_{50}N_{50}P_{25}$ accumulated maximum Mn and was statistically similar with 100%ww$K_{25}N_{50}P_{25}$. At 55 DAS, it was 50%ww$K_{25}N_{50}P_{25}$, which was statistically similar with 100%ww$K_{12.5}N_{50}P_{25}$, and 50%ww$K_{12.5}N_{50}P_{25}$. At last stage, 50%ww$K_0N_0P_0$ accumulated more Mn and was equally effective with 50%ww$K_{50}N_{50}P_{25}$ and 100%ww$K_{25}N_{50}P_{25}$.

**4.4.2.7 Zinc:** In leaf Zn concentration generally increased with K doses at all the three stages. Its concentration was more or less similar in leaf and root. The concentration generally decreased with growth. In root, at 40 and 55 DAS, 50%ww was responsible for maximum Zn content, and at 70 DAS, it was 100%ww (Table 58). At 40 DAS, $K_{50}$ registered maximum content at 55 DAS, $K_{12.5}$ accumulated more Zn and was statistically equal to $K_{50}$. While at 70 DAS, $K_{12.5}$ was statistically at par with other K doses. Among the interactions, Zn content was more in 50%ww$K_{50}N_{50}P_{25}$ and it was statistically similar with other interactions followed by 100%ww$K_{50}N_{50}P_{25}$,

$100\%wwK_{25}N_{50}P_{25}$, and $50\%wwK_{25}N_{50}P_{25}$. The last treatment was at par with $100\%wwK_{12.5}N_{50}P_{25}$ and $100\%wwK_0N_0P_0$. At 55 DAS, $50\%wwK_{12.5}N_{50}P_{25}$ had more Zn content and it was statistically similar with $100\%wwK_{12.5}N_{50}P_{25}$, $50\%wwK_{25}N_{50}P_{25}$, $100\%wwK_{50}N_{50}P_{25}$ $50\%wwK_0N_0P_0$, and $50\%wwK_{50}N_{50}P_{25}$. While at the last stage, $100\%wwK_{50}N_{50}P_{25}$ gave more value which was also statistically equal to $100\%wwK_{12.5}N_{50}P_{25}$ and $100\%wwK_{25}N_{50}P_{25}$. In case of leaf, at 40 DAS, 100%ww whereas at 55 and 70 DAS, 50%ww accumulated higher Zn content. At 55 and 70 DAS, $K_{50}$ was also critically different with other treatments. At 55 DAS, interaction $50\%wwK_{50}N_{50}P_{25}$ registered higher Zn content followed by $50\%wwK_{12.5}N_{50}P_{25}$ and $100\%wwK_{25}N_{50}P_{25}$. Last treatment was also at par with $100\%wwK_{50}N_{50}P_{25}$ and $100\%wwK_{12.5}N_{50}P_{25}$. While at the last sampling, it was $50\%wwK_{50}N_{50}P_{25}$. It was also equal in effect with 50% $wwK_{25}N_{50}P_{25}$, $50\%wwK_0N_0P_0$ and $50\%wwK_{12.5}N_{50}P_{25}$.

**Table: 56 Effect of 50%ww and 100%ww on Copper (mg/kg DW) in root and leaf of turnip (*Brassica rapa*) under different levels of potassium.**

| Copper in root | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $K_0$ | 1.50 | 2.50 | 2.00 | 5.0 | 10.0 | 7.5 | 3.5 | 1.0 | 2.25 |
| $K_{12.5}$ | 8.55 | 1.75 | 5.15 | 16.5 | 14.9 | 15.7 | 12.9 | 16.1 | 14.5 |
| $K_{25}$ | 3.10 | 2.25 | 2.68 | 17.9 | 13.8 | 15.8 | 11.2 | 15.1 | 13.1 |
| $K_{50}$ | 0.00 | 1.60 | 0.80 | 14.8 | 16.3 | 15.5 | 9.90 | 12.4 | 11.1 |
| Mean | 3.29 | 2.03 | | 13.51 | 13.73 | | 9.36 | 11.11 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 0.376 | 0.205 | 0.507 |
| Treatment | 0.532 | 0.289 | 0.717 |
| Interaction | 0.752 | 0.409 | 1.014 |

| Copper in leaf | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $K_0$ | 9.30 | 12.1 | 10.7 | 4.00 | 4.50 | 4.25 | 0.25 | 0.30 | 0.28 |
| $K_{12.5}$ | 6.45 | 12.2 | 9.33 | 8.95 | 6.65 | 7.80 | 0.15 | 2.15 | 1.15 |
| $K_{25}$ | 9.95 | 13.4 | 11.7 | 5.40 | 5.90 | 5.65 | N.D. | 0.80 | 0.40 |
| $K_{50}$ | 12.1 | 13.0 | 12.6 | 7.95 | 5.15 | 6.55 | N.D. | 0.45 | 0.23 |
| Mean | 9.45 | 12.66 | | 6.58 | 5.55 | | 0.10 | 0.93 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 0.445 | 0.277 | 0.037 |
| Treatment | 0.630 | 0.392 | 0.052 |
| Interaction | 0.890 | 0.554 | 0.073 |

N.B: Subscript values denote the amount of potassium (K) in kg $ha^{-1}$. A uniform dose of nitrogen @ 50 kg $ha^{-1}$ ($N_{50}$) and of potassium @ 25 kg $ha^{-1}$ ($P_{25}$) was also applied basally. C.D: Critical Difference. DW: Dry Weight, N.D: Not Detectable. DAS: Days After Sowing, WW: Wastewater.

**Table: 57 Effect of 50%ww and 100%ww on Manganese (mg/kg DW) in root and leaf of turnip (*Brassica rapa*) under different levels of potassium.**

| | Manganese in root | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $K_0$ | 71.0 | 82.0 | 76.5 | 41.1 | 73.0 | 57.05 | 40.7 | 52.4 | 46.54 |
| $K_{12.5}$ | 90.2 | 81.4 | 85.8 | 42.1 | 43.1 | 42.60 | 47.3 | 50.1 | 48.67 |
| $K_{25}$ | 82.2 | 107.2 | 94.7 | 42.8 | 36.9 | 39.85 | 43.7 | 49.0 | 46.37 |
| $K_{50}$ | 129.8 | 98.0 | 113.9 | 44.5 | 40.5 | 42.50 | 43.3 | 43.7 | 43.49 |
| Mean | 93.3 | 92.15 | | 42.63 | 48.38 | | 43.74 | 48.79 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 1.119 | 1.922 | 1.944 |
| Treatment | 1.583 | 2.717 | 2.750 |
| Interaction | 2.238 | 3.843 | 3.889 |

| | Manganese in leaf | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling days (DAS) | | | | | | | | |
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $K_0$ | 81.3 | 77.3 | 79.3 | 80.9 | 78.5 | 79.7 | 98.7 | 61.4 | 80.1 |
| $K_{12.5}$ | 81.5 | 79.3 | 80.4 | 119.5 | 119.5 | 119.5 | 85.7 | 79.7 | 82.7 |
| $K_{25}$ | 85.7 | 99.3 | 92.5 | 125.3 | 104.7 | 115.0 | 85.9 | 93.9 | 89.9 |
| $K_{50}$ | 101.7 | 84.0 | 92.9 | 110.0 | 106.5 | 108.3 | 94.2 | 84.5 | 89.4 |
| Mean | 87.55 | 84.98 | | 108.93 | 102.3 | | 91.13 | 79.88 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 2.40 | 4.59 | 3.62 |
| Treatment | 3.39 | 6.50 | 5.12 |
| Interaction | 4.80 | 9.19 | 7.24 |

N.B: Subscript values denote the amount of potassium (K) in kg $ha^{-1}$. A uniform dose of nitrogen @ 50 kg $ha^{-1}$ ($N_{50}$) and of potassium @ 25 kg $ha^{-1}$ ($P_{25}$) was also applied basally. C.D: Critical Difference, DW: Dry Weight, DAS: Days After Sowing, WW: Wastewater.

**Table: 58 Effect of 50%ww and 100%ww on zinc (mg/kg DW) in root and leaf of turnip (*Brassica rapa*) under different levels of potassium.**

**Zinc in root**

| | Sampling days (DAS) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $K_0$ | 76.0 | 92.0 | 84.0 | 83.0 | 65.0 | 74.0 | 43.2 | 42.3 | 42.75 |
| $K_{12.5}$ | 78.5 | 96.3 | 87.4 | 84.3 | 84.1 | 84.2 | 71.1 | 81.9 | 76.50 |
| $K_{25}$ | 96.4 | 120.8 | 108.6 | 83.9 | 74.3 | 79.1 | 67.9 | 80.5 | 74.20 |
| $K_{50}$ | 141.2 | 135.6 | 138.4 | 81.8 | 83.2 | 82.5 | 66.3 | 84.2 | 75.25 |
| Mean | 98.03 | 111.18 | | 83.25 | 76.65 | | 62.13 | 72.23 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 4.329 | 3.394 | 2.937 |
| Treatment | 6.123 | 4.799 | 4.154 |
| Interaction | 8.659 | 6.787 | 5.874 |

**Zinc in leaf**

| | Sampling days (DAS) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 40 | | | 55 | | | 70 | | |
| | wastewater | | | wastewater | | | wastewater | | |
| Fertilizer | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean | 50%ww | 100%ww | Mean |
| $K_0$ | 74.0 | 82.0 | 78.0 | 70.0 | 75.9 | 73.0 | 83.9 | 58.4 | 71.2 |
| $K_{12.5}$ | 77.9 | 87.7 | 82.8 | 103.7 | 89.7 | 96.7 | 82.1 | 76.3 | 79.2 |
| $K_{25}$ | 77.9 | 85.1 | 81.5 | 71.4 | 94.2 | 82.8 | 84.7 | 61.2 | 73.0 |
| $K_{50}$ | 78.5 | 84.0 | 81.3 | 121.4 | 93.6 | 107.5 | 88.7 | 81.3 | 85.0 |
| Mean | 77.1 | 84.7 | | 91.6 | 88.4 | | 84.9 | 69.3 | |

| C.D. at 5% | 40 | 55 | 70 |
|---|---|---|---|
| Water | 3.37 | 3.11 | 3.30 |
| Treatment | NS | 4.39 | 4.67 |
| Interaction | NS | 6.21 | 6.60 |

N.B: Subscript values denote the amount of potassium (K) in kg $ha^{-1}$. A uniform dose of nitrogen @ 50 kg $ha^{-1}$ ($N_{50}$) and of potassium @ 25 kg $ha^{-1}$ ($P_{25}$) was also applied basally. C.D: Critical Difference. DW: Dry Weight, N.S: Non Significant, DAS: Days After Sowing, WW: Wastewater.

CHAPTER 5

# DISCUSSION

## 5.1 WATER

The quality of wastewater and tap water was assessed with respect to various physico-chemical properties and some of the heavy metals (Table 6) showing FAO limits for irrigation water. Both waters were alkaline in nature as the pH range of the wastewater was 7.24-7.50 (38 ML/d), 7.10-7.46 (34 ML/d) and for tap water it was 7.35-7.52. Its electrical conductivity (EC) was 827-858 µmhos/cm (38 ML/d), 1598-1890 µmhos/cm (34 ML/d) which was expectedly higher than the tap water having, 608-625 µmhos/cm. Therefore, the two wastewaters may be placed under medium to high salinity category (750-2250, µmhos/cm Wilcox, 1955) which is supposed to be safe for irrigation with permeable soils and moderate leaching. The main effect of high EC and total dissolved solids (TDS) on crop productivity is the inability of the plant to compete with ions in the soil solution for water as higher EC and TDS will adversely affect the availability of water. The dissolved oxygen (DO) was low (2.4-3.8 mg/L) in 38 ML/d while it was zero in 34 ML/d wastewater whereas, it ranged between 4.6-4.8 mg/L in tap water. It may be pointed out that DO determination is vital for ensuring aerobic conditions in waters that receive polluting matter in the form of sewage, industrial wastes and treatment plant effluents. On the contrary biochemical oxygen demand (BOD) of the samples was 32-47 mg/L in 34 ML/d, whereas it was 20-33 mg/L in 38 ML/d while it was nil in tap water. Similarly chemical oxygen demand (COD) value was 110-150 mg/L in 34 ML/d and it was comparatively less (49-100 mg/L) in 38 ML/d while it was not observed in tap water. On the basis of BOD, test made to determine the strength or polluting power of sewage, or industrial effluents and on the basis of COD, the wastewater may be rated as suitable for irrigation when compared with the prescribed limits of 100 and 250 mg/L for BOD and COD, respectively (Pescod, 1992) although some of the salts and heavy metals should be taken up seriously specially in case of 34 ML/d waste water. The total alkalinity of wastewater samples was in the range of 390-400 mg/L (38 ML/d), 490-500 (34 ML/d) while in tap water it was 252-265 mg/L.

The concentration of almost all the elements analyzed especially the essential macro and micro nutrients were higher in wastewater, than the tap water. This implies that its application after irrigation may provide adequate essential and beneficial nutrient which supposed to be the main reason of waste water use in crop cultivation with another reason may be to avoid its disposal in a water body. Tap water showed complete absence of $NH_4$-N although it was present in the range of 27-50 mg/L in 38 ML/d, and 63-75 mg/L in 34 ML/d. It may also be pointed out that the phosphorus content in waste water was 5.1-5.7 (38 ML/d), and 5.6-10.4 mg/L (34 ML/d) which may be due to the mixing of either house hold detergents waste or some industrial wastes containing phosphates. Together nitrates and phosphates are responsible for increasing the fertility of the water bodies where such wastes are dumped causing eutrophication because of which some of the beautiful lakes and ponds have lost their beauty, quality of water and depth. In addition K content was also present 13.8-14.6 (38 ML/d), 22.2-24.0 mg/L (34 ML/d) and its range in tap water was between 3.2-3.9 mg/L. Therefore, the presence of these three major macro nutrients along with some other macro (Mg, Ca, S) micro (Fe, Cu, Mn, Zn, Ni) and beneficial elements (Na) makes it suitable in terms of nutrients supply. It may be pointed out the heavy metals present in wastewater (Table-6) and tap water (Cd, Cr, Ni, Fe Cu, Mn and Zn) were within the permissible limits as per standards prescribed for land disposal (Pescod, 1992, Ayers and Westcot, 1994).

It was further observed that wastewater also contained total coliform and fecal coliform in the range of $20x10^3$-$23x10^4$ (38 ML/d), $21x10^4$-$93x10^6$ (34 ML/d) while these were not found in tap water. These values were much higher than the permissible limits (i.e. 1000MPN/100mL) specified by WHO for unrestricted irrigation (WHO, 1989). Therefore, the farmers who are dependent upon this water for irrigation must be warned for the precautions to be undertaken during irrigation operation and also the consumers as turnips sometimes are eaten raw and even if after cooking.

## 5.2 SOIL

The texture of the soil was sandy loam (Table-7) and loam may be defined as a soil that does not exhibit the dominant physical properties of any one i.e. sand, silt, or clay (Miller and Donahue, 1990). This has great influence on root growth and its ability to absorb water and nutrients in quantities sufficient for optimum growth which is most suited for root vegetables. The organic matter content was within the range of 0.72-0.95% as high organic carbon means immobilization of many metal ions. The presence of organic matter is important as it is also a source of plant nutrients in addition to its role to provide organic colloids of soil. Therefore, it increases the ion exchange capacity, water holding capacity and soil fertility as it regulates the soil water and air supply, which in turn control the rate at which nutrients are absorbed by the roots. Values of soil pH fall in a range of 7.92-8.11 and the uptake of various plant nutrients is pH dependent. Generally anions including nitrate and phosphates are taken up at pH range close to our experimental soil while the uptake of cations is more close to neutral or 6.5 pH (Mengel and Kirkby, 1996). In this context a figure containing 51 types of crops may be mentioned where pH range was 4.5-7.5 for most of the crops while for radish it was 5.5-6.5 a close relative of turnip which was not included in the list (Havlin et al, 1999). Therefore, the soil pH was not ideal for this crop. However, the soil contained 200-245 mg/kg P, 50-80 mg/kg K, and 146-224 mg/kg N, which may be an additional source of these macronutrients (Table 7). Another important characteristic was the conductivity which was between 283-320 μmhos/cm therefore, may be termed as medium (200-800, μmhos/cm) and it is optimum for most plants as it usually indicates well fertilized soil, although salt sensitive plants may be adversely affected due to injury (Bear, 1964). It may be pointed out that some of the factors known to affect the solubility and availability of nutrients include CEC, soil texture, pH, and organic matter content (Haghiri, 1974; Williams et al, 1980; Verloo and Eeckhout, 1990). On the basis of these characteristics soil may be termed as suitable for crop cultivation except the pH as pointed out above. Heavy metals were also listed in table 7, where Cd, Cr, Ni, Fe, Cu, Mn and Zn were in the range 8-15, 35-38, 78-162, 13100-16000, 18-27, 300-350 and 72-195 mg/Kg. Again out of seven heavy metals tested five are placed under the category of essential which are needed for the normal growth and development of any crop including the turnip and remaining two (Cd, Cr) are heavy metals which may be toxic.

### 5.3 PLANT (Turnip)

#### *5.3.1 Effect of 38 ML/d municipal wastewater (Experiment I-II)*

Growth was significantly affected by the wastewater and 100%ww alone was better among four concentrations studied (Table-1) as it increased most of the growth parameters (Tables 13, 14, 15). It may be recalled that the presence of sufficient essential macro nutrients plus Na which is categorized as beneficial element for plants (Salisbury and Ross, 1992), in addition to trace elements like Cl, Fe, Cu, Mn, Zn, Ni cumulatively have played a key role in enhanced growth. Because they were available to plants due to regular watering and the role of these nutrients are well documented. For example, consistent supply of N in two forms ($NH_4^+$ and $NO_3^-$) present in wastewater (Table 6) could have played a key role in plant fresh weight, (Table 13, & 23,) by maintaining adequate cation-anion ratio. While P stands second after N in plant nutrition and is also important for all forms of life because of its role in energy transfer via. ATP. Like nitrogen and phosphorus, presence of potassium also enhanced the growth as sufficient K was present in wastewater as well as in soil (Table 7). It is thought to be essential for the formation and translocation of carbohydrates and is needed in large quantities by most root crops as may be observed in our study (Tables 23, 24, & 25). In the low $K^+$ treatment, growth rate, cell size and water content of the tissue may be reduced which are essential growth component of turnip as may be the case under K deficient dose (Table 23, 24, & 25) where growth was adversely affected. Another macro nutrient present in waste water was Ca which has an important role in the structure and permeability of cell membranes, therefore its presence (76-78 mg/L) has also provided some regulation of cation uptake (Schmit, 1981) and is also essential for cell elongation and division thereby promoting the growth. Magnesium, another essential macro nutrient (40.5-45.1 mg/L) is an important constituent of chlorophyll molecule and without it green plant would fail to carry on photosynthesis (Marschner,2002). Similarly sulphur, is absorbed by plant root almost exclusively as the sulphate ion, ($SO_4^{-2}$) which is so important for this crop and it is present in equal or lesser amounts than P in plants as wheat, corn, beans and potatoes but in larger amounts in alfaalfa, cabbage, and turnips.

Among micro nutrients $Cl^-$ could have played a role in the opening and closing of stomata which is so vital for gaseous exchange for greater photosynthesis. It is also required in the cell division in leaves and shoots and plants deprived of it tend to reduced growth (Hopkins, 1995). Its excess if it approaches 300 ppm can be harmful but it was in permissible limit (Table 6) in 38ML/d wastewater. Among other micro nutrients sufficiency range of iron in plant tissue is normally between 50 and 250 ppm and it is a structural component of some important molecules, while Cu acts as an electron carrier, and part of plastocyanin which has an important role in photosynthesis and dry matter accumulation. Similarly, the involvement of Mn in photosynthesis, particularly in the evolution of $O_2$, is well known while zinc concentration ranges from 25 to 150 ppm in plants and its absence or deficiency adversely affects the leaf development as leaf margins are often distorted and it is also essential for certain enzymes (Marschner, 2002). Ni is the latest (1987) nutrient recognized as essential for higher plants, since $Cl^-$ was established as an essential micro nutrient in the year 1954. It is essential for plants supplied with urea and for those in which ureids are important in nitrogen metabolism. On the contrary, Na comes under the category of beneficial elements which was also present in wastewater and it is beneficial for turnips, beets, sugar beets, and celery as these crops grow better in its presence and may actually require it (Salisbury and Ross, 1992). Contrary to essential and beneficial nutrients Cd which comes under the category of heavy metals is considered to be a nonessential element for plants, and categorized as toxic element without any known physiological function in plants. Similarly, there is no evidence yet of an essential role of Cr in plant metabolism, although Mertz, (1969) has reviewed the positive effect on plant growth of Cr application to soils having low soluble Cr content. In this experiment 14 essential and beneficial elements were thus estimated in wastewater and most of them were in the permissible range as per the FAO limits for irrigation water. The lower concentration of wastewater also improved the growth when compaired with tap water as most of these essential nutrients were also present although in lesser quantity due to its dilution with tap water. These results were in agreement with the study of Inam et al (1993), Aziz et al (1994), who worked on Mathura refinery wastewater, Javid et al, (2003) on thermal power plant waste water, Jacobs and Ward, (2006), Nair et al, (2008), and Shahroz, (2009), on city waste water.

Different doses of P were also applied with tap water where $TWP_{25}$ was optimum (Table 13, 14, 15) for most of the growth parameters, while $TWP_{50}$ was excessive, as reduction in growth was observed (Table 13, 14, 15). Among essential nutrients, P is often limiting due to its low availability, therefore, its supply by any means may improve the growth as observed in experiment-I. $P_{25}$ without waste water was optimum in comparision with $P_{50}$ which may be because of the nature of turnip which is placed among the short duration crops where growth responses to even low applied phosphorus tend to persist until harvest (Engelstad and Terman, 1967). It may also be noted that the increased plant height and leaf number (Table 13, 15) was probably responsible for the sufficient production of photosynthates leading to more dry weight (Table 13). Contrary to sufficiency level, plants suffering from its deficiency showed reduction in number of leaves (Lynch et al, 1991) and low photosynthetic activity (Avdeeva and Andreeva, 1974) thus decreasing the growth as may be observed (Table 13, 14, 15) under $P_{12.5}$ therefore, proved deficient (Table 13, 14, 15) which is always associated with decrease in yield, stunted plants and delayed maturity. On the contrary higher dose ($P_{50}$) was excessive which must be avoided as nutrients either gets wasted or may even lead to decrease in yield (Table 13, 14, 15). It may also be noted that tap water alone was poor in plant fresh weight in comparison when it was supplemented with doses of P as the growth is a result of meristematic cell division, expansion and differentiation which directly depends upon the supply and availability of nutrients (Moorby and Besford, 1983).

In the second experiment, NPK fertilizers were added with different concentrations of wastewater and by this way we aimed to determine the additional increase in productivity. Vegetable crops are known to require heavy doses of organic as well as inorganic fertilizers which should be applied according to the pattern of their root growth (Chauhan, 1968). For example in case of carrot, raddish and turnip which are cultivated mainly for their quick growing roots the soil should be so fertilized periodically that the nutrients may remain readily available to the roots of the plants as they grow. Vegetables growers therefore, give considerable attention to fertilizer application for maintaining high productivity levels and the effectiveness of a fertilizer depends on its quantity, availability to plants and mode of its application as raising of crop plants year after year in the same field results in deficiency of heavily consumed nutrients, like NPK, if these are not added adequately and regularly before each sowing (Miller and Donahue, 1990). Therefore, in our study, 50%ww$N_{25}P_{25}K_{25}$ although lower in quantity but supplemented with adequate nutrients of waste water gave more plant fresh weight (Table 23) and dry weight, leaf fresh weight, and root diameter (Table 13, 14, 15) when compared with 50%ww alone (Experiment-I) indicating the role and importance of NPK fertilizers (Experiment-II) in promoting the turnip growth.

It was evident from the work of Thapar, (1960) who suggested that the requirement of NPK for turnip may be 60 kg N, 40 kg $P_2O_5$ and 40 kg $K_2O$/ha applied at the time of knob formation for good yield while in our case the requirement became lesser due to waste water proving our assumption of fertilizer economy mentioned in chapter-I. On the contrary 100%ww$N_{100}P_{100}K_{100}$ recorded adverse effect expectedly due to decrease in plant fresh weight and dry weight, leaf fresh weight and root diameter which was not surprising as high NPK may be responsible for physiological disorders eg. Increasing levels of nitrogen may lead to excess soluble amino acids which cannot be used for growth process because of relative shortage of other nutrients. Similarly, high P can reduce growth and yield by reducing the availability of other nutrients like Zn while high dose of K can depress the uptake of other cations (Mengel and Kirkby, 1996). In addition presence of some heavy metals and other nutrients in 100% waste water further compounded the ill effects of excessive nutrients which could have reduced the plant growth in general. It may also be added that toxicity of higher dose of N given as urea may be due to the accumulation of $NH_4^+$ from hydrolysis of urea and also the damaged due to the accumulation of $NO_2$ (Court et al.,1964).

### *5.3.2 Effect of 34 ML/d municipal wastewater (Experiment III-IV)*

In experiment-III, 34ML/d wastewater after dilution and lower phosphorus dose 50%ww$P_{12.5}$ proved beneficial in enhancing the growth as plant fresh weight (Table 33) and root fresh weight were maximum which was at par with 50%ww$P_{25}$ indicating the usefulness of wastewater. The role of the nutrients present in waste water has already been discussed under 38 ML/d waste water, with the difference here that 50%ww was more effective in case of 34 ML/d, because some of the ions were quantitatively more. Although even 100%ww of 34 ML/d, was better in some of the growth parameters. The observed increase in growth and size of root is dependent largely on nutrient and water supply during the early growth of the crop. Therefore, enhanced plant growth at this stage and the increased leaf area was responsible for bigger roots. The more quickly in the period of growth, is developments of leaf (Table 38, 51) better are the chances for $CO_2$ assimilation and translocation of photosynthates towards the root. While higher P dose ($P_{50}$) with 50%ww was excessive as it decreased the plant growth (Table 33, 35, 37). Such an adverse effect of higher fertilizer dose is observed very commonly as the crops do not recover fully from the adverse effect on growth caused due to unfavourable conditions in the early stages as reported by Stanhill, (1958) in turnip and Hammet et al, (1984) in sweet potato. Root diameter has not shown excessive effect of $P_{50}$ alone while leaf fresh weight, another important growth parameter in turnip, was decreased with this dose. It may be pointed out that root growth often increased if sufficient phosphorus is provided, relative to shoot growth (Salisbury and Ross, 1992) as P is an integral part of many important metabolites (Devlin and Witham, 1986). It also promotes ribulose-1, 5-biphosphate regeneration (Rao and Terry, 1989; Fredeen et al, 1990), ribulose-1, 5-bisphosphate carboxylase and adenosine triphosphate synthesis (Dietz and Foyer, 1986) and carbon dioxide assimilation (Longstreth and Nobel, 1980) which were helpful in enhancing the photosynthetic process thereby enhanced root and shoot growth as observed in this study. These results also corroborate the findings of Sheoran et al, (1999), Greenwood et al, (2001) and Zheng-miao et al (2006) on growth and P fertilizer.

Similarly 50%ww also proved effective in Experiment-IV for enhancing the growth parameters over 100%ww because without dilution it proved harmfull due to excessive ion contents although it enhanced leaf fresh weight and dry weight. Thus the combination 50%ww$K_{12.5}N_{50}P_{25}$ recorded the maximum plant growth which was also at par with 50%ww$K_{25}N_{50}P_{25}$ showing the economy of K fertilizer also. As pointed out earlier K has many roles to play because it is an activator of many enzymes that are essential for photosynthesis and respiration, and it also activates enzymes needed to form starch and proteins. This element is also a major contributor to the osmotic potential of cells and therefore to their turgor pressures an important feature of root crops. It may also be mentioned that K also promotes translocation of sugars from the leaves to the tubers of potatoes because of which starch content of the tubers is high with well supplied K (Lachover and Arnon, 1966).

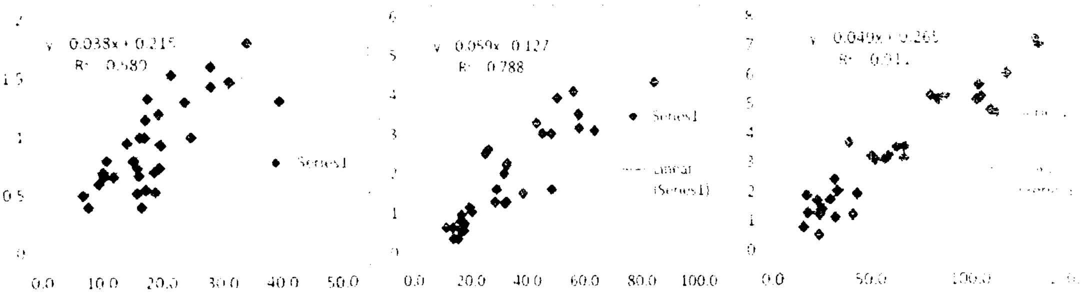
## 5.4 GROWTH RESPONSE

Plant fresh weight and dry weight, root fresh weight and dry weight, leaf fresh weight and dry weight, root diameter and leaf number in some cases increased linearly with the advancement of age up to 70 DAS in all the experiments which is a common feature in many crops as log phase of growth remained continued up to 70 DAS in turnip under present conditions. It is also evident from the Fig, 14 where relationship with plant fresh weight and root fresh weight (Fig. 12a-c), leaf fresh weight (Fig. 13a-c) and root diameter (Fig. 14a-c) were taken up at different stages of growth with a linear increase in all the experiments. On the contrary the increases in leaf number from 40 to 55 DAS followed by a decline in some cases was observed which may be due to the senescence in older leaves at late stage of growth, which is an integral and important plant development and physiological activity and is under genetic control (Thomas and Stoddart, 1980). This also strengthens the view expressed by Bidwell, (1979) that due to the enhancement in root size a death message comes to the older leaves as most of the mobile nutrients gets translocated towards the developing organs i.e. root in the present study.

Correlation coefficient ($r^2$) values were also calculated between plant fresh weight and root fresh weight, leaf fresh weight, root diameter. For plant fresh weight and root fresh weight where $r^2$ values were 0.589, 0.788, and 0.911 at three stages of growth. For plant fresh weight and leaf fresh weight these were 0.950, 0.924, 0.598, and for root diameter the values were 0.573, 0.807, and 0.912 at 40, 55 and 70 DAS respectively. These results indicate that root fresh weight and root diameter showed a good relationship at harvest stage between two parameters while leaf fresh weight showed a good relationship at early stage of growth.

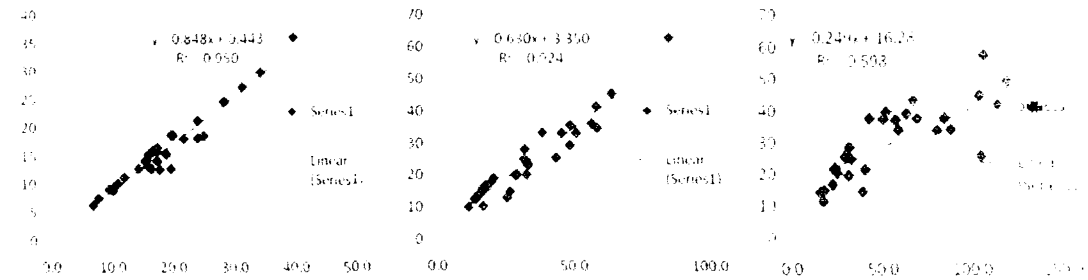
## 5.5 HEAVY METALS

**5.5.1 Cadmium:** Several elements are known to interact with it in both uptake and in biochemical roles. Mention may be made of Cd-Zn, where depressing as well as enhancing effects of each have been reported, while inhibitory effect of Cu on Cd absorption and enhancing effect of P on Cd uptake have also been observed earlier (Pendias and Pendias, 1992). Similarly, in the present study (Experiment-I) different doses of P with tap water enhanced its concentration which may be because of the



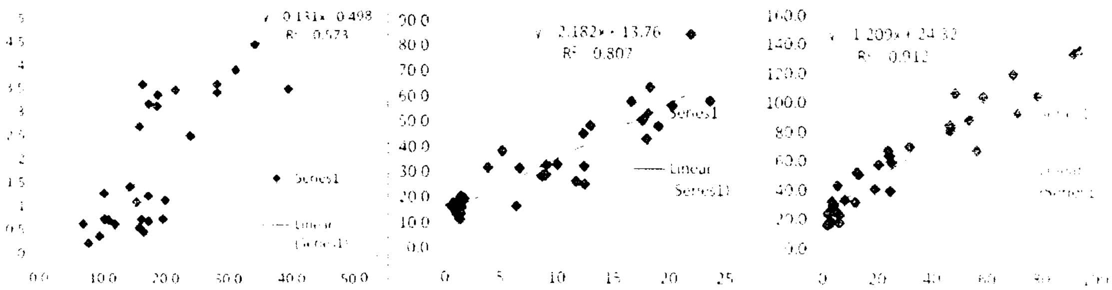
12-a 12-b 12-c

**Fig:12 a-c,** Relationship between plant fresh weight and root fresh weight at 40, 55, and 70 DAS in experiment I-IV.



13-a 13-b 13-c

**Fig: 13 a-c,** Relationship between plant fresh weight and leaf fresh weight at 40, 55, and 70 DAS in experiment I-IV.



14-a 14-b 14-c

**Fig: 14 a-c,** Relationship between plant fresh weight and root diameter at 40, 55, and 70 DAS in experiment I-IV.

presence of Cd (0.1-170 ppm) in phosphatic fertilizers. Likewise its concentration was more in plants grown under wastewater as Cd was also present in wastewater (Table 6) although concentration of waste water was not much effective in accumulation of Cd in our study as ion uptake is not concentration dependent in many plants for a number of elements (Devlin and Witham, 1986).

When K was applied with tap water (Experiment-II) its concentration generally increased as Cd uptake and translocation mechanism are influenced by the supply of other nutrients including K. Naturally, with increasing doses of NPK fertilizers under wastewater, Cd was expectedly increased because of its presence in both sources. In this context it may be pointed out that when plants are grown on contaminated soil, Cd is very likely to be concentrated in roots and leafy vegetables such as spinach, and turnip, which may be considered to be the main routes of Cd supply to man (Pendias and Pendias, 1992). In case of experiment-III its concentration was increased with P doses in case of leaf only but it decreased in root. Surprisingly both increased and decreased content of Cd under phosphate treatment were reported earlier. In general Cd was more in roots than the leaf in all the experiments (Fig. 15 a, b) which was also in agreement with the work of Demirezen and Aksoy, 2004. Ability of plants to translocate heavy metals from roots to shoots is measured by calculating translocation factor (TF). TF value of more than 1 suggested that heavy metals are readily transported from roots to shoots whereas values less than 1 signify more accumulation of heavy metals in root. In our study data indicated that the metal was largely retained in roots as confirmed by TF values which were <1 at 40 and 55 DAS, because it is both metabolically and passively taken up (Demirezen and Aksoy, 2004) although at 70 DAS, this value was >1 in some cases. Significantly the level of Cd in root in the majority of the cases (Experiment- II, III, and IV) exceeded the toxic levels at 40 DAS, while at 55 DAS, it exceeded in experiment I and III only. On the contrary at harvest stage Cd was surprisingly below the toxic levels in III and IV experiments. It was obviously due to the increased root fresh weight, increased root diameter and plant fresh weight at this stage which was supposed to be responsible for its dilution although the total Cd content could have remained unchanged. It may be relevant here to point out the work of Chaney and Honrich, (1977) who have reviewed the work on Cd and reported much difference in the ability to absorb it, where lowest

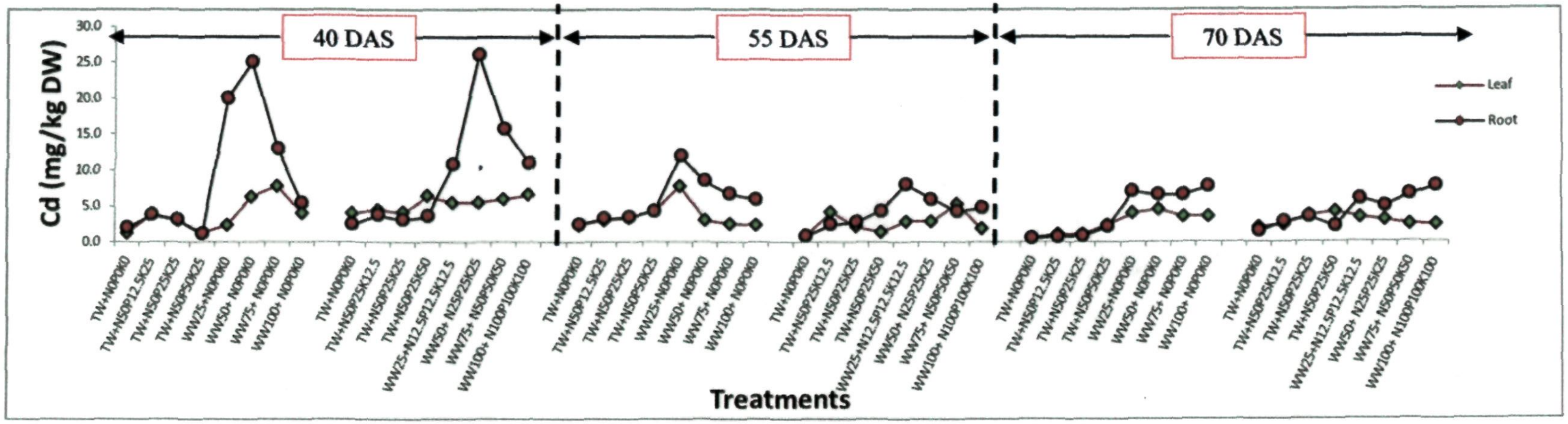



Fig: 15 a, Cadmium concentration in root and leaf in experiments I-II at three stages

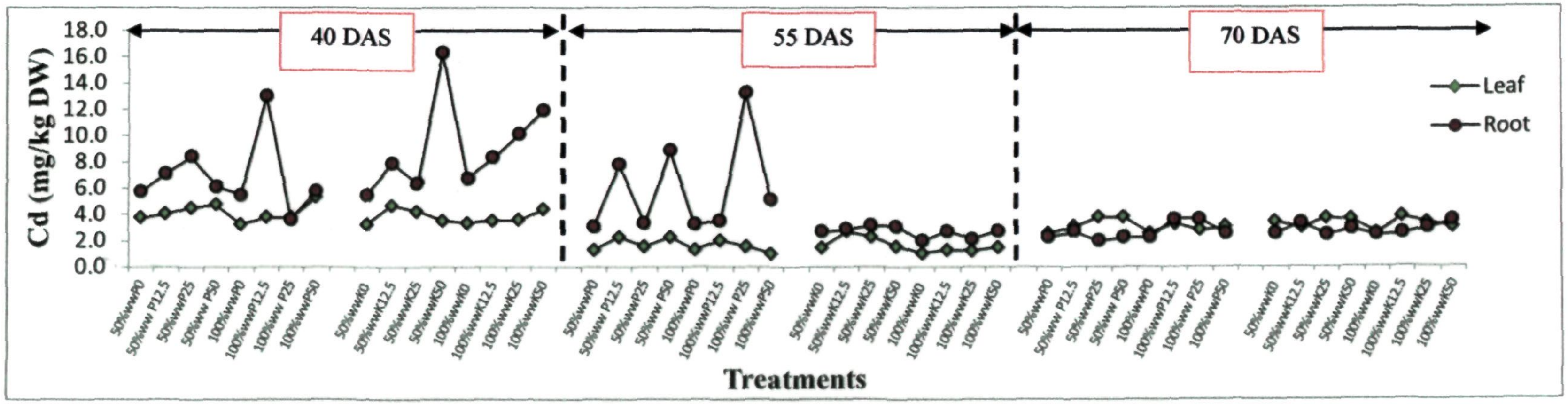



Fig: 15 b, Cadmium concentration in root and leaf in experiments III-IV at three stages concentration was observed in rice, sudan grass and clover and higher in spinach and turnip. On the contrary Cd in leaf was below the toxic levels in all the experiments at last stage of sampling as it was generally retained by the roots instead of transporting it towards the shoot.

**5.5.2 Chromium:** There is not much literature on Cr in plants and generally its level in plants material varied in the order of 0.02-0.2 ppm (DW). In experiment-I and II surprisingly Cr was not detected in both organs among the tap water treatments while in wastewater it was found only in root (Experiment-I) which apparently showed that it is relatively immobile in plants and also less absorbed. In this context it may be observed that a low rate of Cr uptake by plants from the soluble fraction of this metal is related to the mechanism of absorption by roots and its concentration in plants vary widely depending upon the kind of tissues and stage of growth, and the trend in Cr variation appeared to be irregular (Mertz et al, 1974) like the one shown in Fig. 16 a, b. It may also be added that immobility of soil Cr may also be responsible for its inadequate supply to plants as observed in experiment-II where it was 0-0.121mg/L. In addition there were instances where significant amount of Cr was present in soil and still its availability to plants was highly limited as the soil Cr is largely unavailable to plants because it occurs in relatively insoluble compounds and rate of uptake and its translocation is comparatively slow (Mengel and Kirkby, 1996). In experiment-III and IV its concentration was generally more in 100%ww which may be because of its presence (0.003-0.031 mg/L) in it. At early stage of growth Cr was not detected probably it was not taken up at detection level by the root while at harvest it was not detected in leaf also in both experiments (Fig, 16 a, b) which was rather surprising and possibly may be due to differences in genotypes with inherent difference in metal uptake (Greager, 2004). Alternatively it may be because of its release back from plant tissue as metal accumulation depends on both uptake in to the tissue and leakage in to the surrounding medium (Pendias and Pendias 1992). The TF values were generally <1 indicating its higher quantity in root.

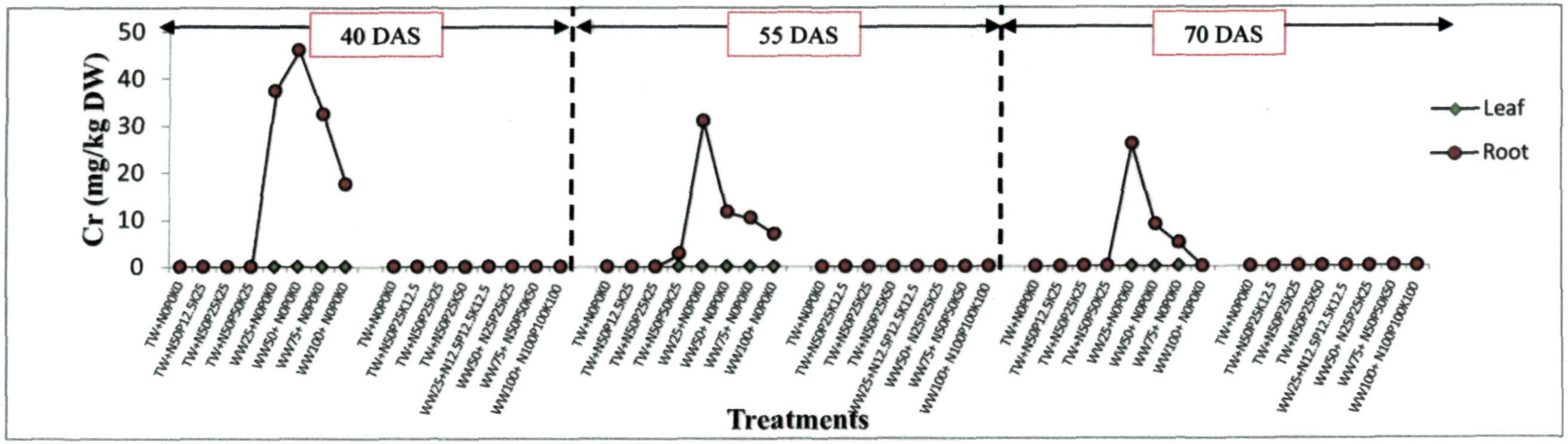



**Fig: 16 a, Chromium concentration in root and leaf in experiments I-II at three stages**

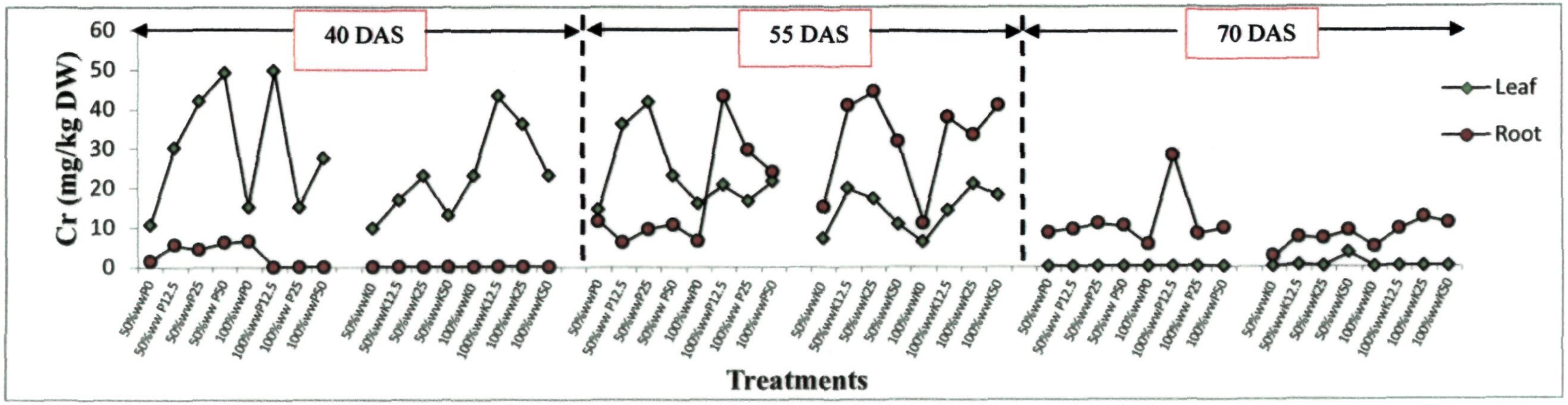



**Fig: 16 b, Chromium concentration in root and leaf in experiments III-IV at three stages**

**5.5.3 Nickel:** Its concentration was generally more under waste water and P doses. Similar observations were made by Cataldo et al, (1978) who observed that when Ni is in the soluble phase, it is readily absorbed by roots in soybean and its uptake by plants is positively correlated with its concentrations in solutions. Under such conditions it is readily and rapidly taken up by plants from soils and until certain Ni concentrations in plant tissues are reached, the absorption is positively correlated with the soil Ni concentrations. While comparing the two waters its concentration was more in waste water than the tap water which was due to its presence in waste water and like Cd it was also independent of waste water concentrations (Experiment-I). Similarly Ni concentration was also enhanced with phosphatic fertilizer due to its presence ranging from 7-38 ppm (Senesi and Polemio, 1981). While in experiment-II its concentration was generally increased due to its easy availability and consistent supply through wastewater (Table 6), soil (Table 7) and NPK fertilizers. Its concentration was more in root at 40 and 70 DAS, while at 55 DAS, it was more in leaf in experiment-III. The same trend was observed in Experiment-IV (Fig: 17 a, b). It may be because of its easy mobility in plants, therefore after initial growth up to 40 DAS, where its concentration was higher it was transported more towards the growing leaves at 55 DAS, stage. However, at later stage due to senescence in some of the older leaves it was transported back towards the sink (root in the present study) where an elevated Ni concentration was observed (fig: 17 a, b). There is not much information about the Ni in vegetables although Shacklette, (1980) reported that the Ni content in vegetables ranges from 0.2 to 3.7 ppm (DW). In our study data indicated that metal accumulated by turnip plants was largely retained in roots as indicated by TF values which were <1 at 40 and 70 DAS, while at 55 DAS, TF value in general was more than >1.

**5.5.4 Iron:** Fe is absorbed by plant roots as $Fe^{+2}$, $Fe^{+3}$ and as organically complexed or chelated. It is a structural component of many organic molecules which are involved in oxidation-reduction reactions in plant metabolism. Its uptake and transport between plant organs are highly affected by several plant environmental factors, and its deficiency affects several physiological processes therefore, the plant growth. In experiment-I and I

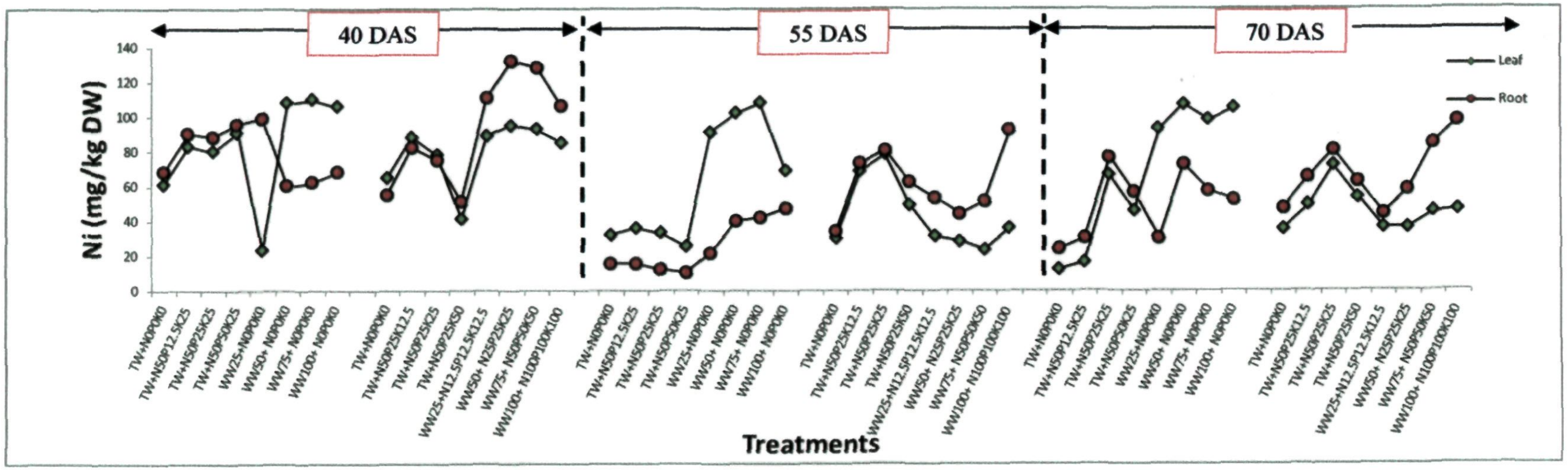



**Fig: 17 a, Nickel concentration in root and leaf in experiments I-II at three stages**

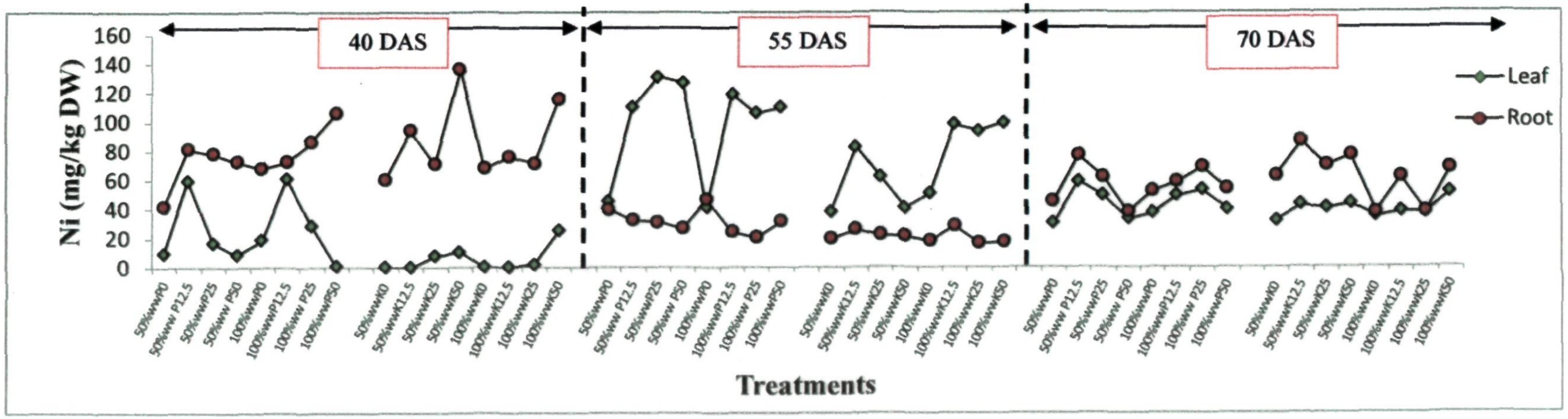



**Fig: 17 b, Nickel concentration in root and leaf in experiments III-IV at three stages**

concentration was generally increased with wastewater than the tap water in case of root but in leaf it was generally more in tap water. In this context it is important to point out that usually more the Fe deficient media, greater the ability of plant to extract more from the media which was in line with our observations also where tap water contained less amount of Fe, even then it was absorbed and accumulated more in leaf. However, in case of wastewater it was more in root which was directly in contant with soil well supplied with wastewater having sufficient (13100-16000 mg/kg) Fe. In this context it may be noted that soils are usually not deficient in Fe but may be deficient in soluble forms therefore, due to timely availablity through continous supply of wastewater its concentration was enhanced. The increase in Fe contents under P and K (Experiment III and IV) fertilizers may be because of their roles in enhancing the root growth thereby the surface area for its greater absorption (Tisdele et al 1995). The TF values were generally >1 in all the experiments proving more concentration in leaf because about 75% of total leaf Fe is associated with chloroplast and up to 90% of Fe leaves occur with lipoprotein of chloroplast and mitochondria membrane. It is structural component of porphyrin, cytochrome, hematin and ferrichrome which are involved in respiration and photosynthesis, therefore its presence in larger amount in leaves was understandable (Havlin et al, 2003).

**5.5.5 Copper:** It is absorbed by plants as the cupric ion ($Cu^{+2}$), and may also be absorbed as a component of either natural or synthetic organic complexes. Its normal concentration in plant tissue ranges from 5 to 20 ppm. In experiment-I and II it was not found in the tap water treatments in both the organs as it might have not been absorbed either completely or up to the detection level as Cu concentration in soil solution is generally quite low. In addition most of the Cu in soils is very insoluble while the soluble Cu is organically complexed and is more strongly bound to organic matter than any other micronutrients which may be another reason for its absence. In addition its concentration was also less after Cr among the seven heavy metals observed in the present study while it was also less in amount in soil after the Cd (Table 7). Therefore, it seems, it has not entered in to the plants up to the level of its detection in leaf and root. On the contrary under waste water and NPK fertilizers (Experiment-II) Cu absorption could have been inhibited due to

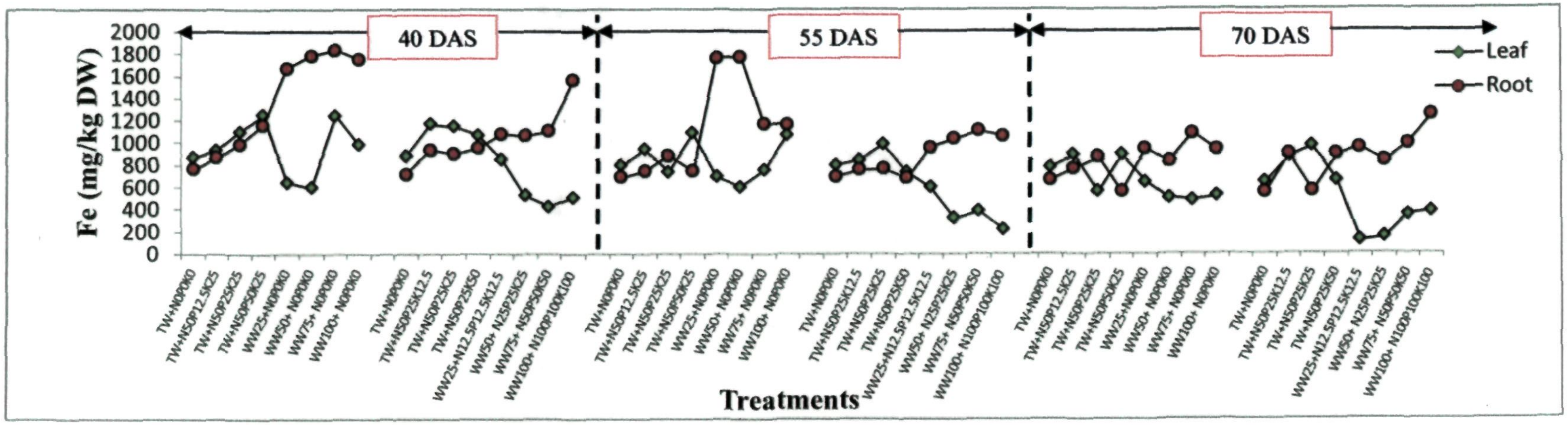



**Fig: 18 a, Iron concentration in root and leaf in experiments I-II at three stages**

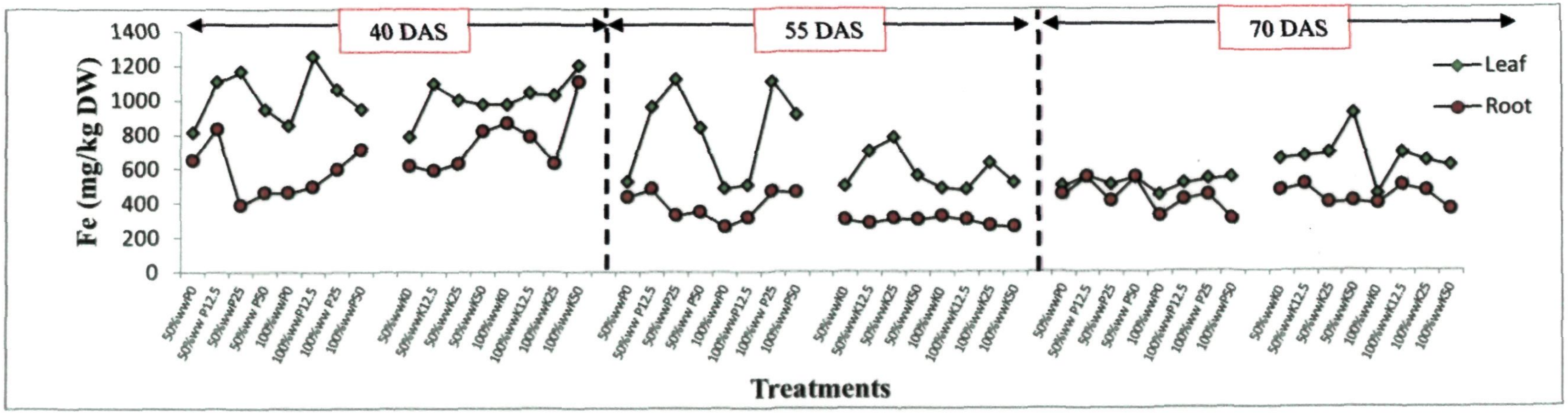



**Fig: 18 b, Iron concentration in root and leaf in experiments III-IV at three stages**

numerous interactions involving Cu and other nutrients like NPK applied as fertilizers which can induce the Cu deficiency. It may also be pointed out that phosphatic fertilization has also decreased the Cu concentration (Experiment-III) as Cu-P antagonism commonly occurs in root media (Pendias and Pendias 1992). While in case of K its concentration was generally decreased with increase in doses due to its interaction with K where potassic fertilizers can also induce Cu deficiency (Tisdele et al 1995). The TF value was generally <1 at 55 and 70 DAS, as the Cu mobility within plant tissues strongly depends on the level of Cu supply and it has low mobility relative to other elements in plants. In addition the distribution of Cu within plants is highly variable as within roots, Cu is associated mainly with cell walls and is largely immobile. The majority of plant species therefore, can accumulate more Cu especially in root as observed at later two stages (Table 20, 30, 43, 56). While at early stage TF value was >1 in both experiments (Experiment III-IV). The highest concentrations of Cu in shoots are always in phases of intensive growth which was evident in our study at 40 days (Table 20, 30, 43, 56).

**5.5.6 Manganese:** Its normal concentration in plants typically ranges from 20 to 500 ppm. In the present study also the range of Mn varied from 30-274 mg/kg. In case of leaf Mn concentration from 15-20 ppm considered deficient. While in the present study considerable higher amount of Mn were observed in leafy part of the turnip (Fig: 20 a, b). In experiment I and II its concentration was more in fertilizer treatments with wastewater which was due to its availability in wastewater (0.072-0.148 mg/L) and fertilizer (40-2,000 ppm). It may also be added that differences in Mn content under different concentrations of wastewater were due to differential absorption by the root (Bowen, 1979). Similarly there was difference in tap water and waste water also (Table 6) where the later source has provided more Mn content to root zone for higher availability and greater uptake. It may be pointed out that potassic fertilizer has great role in Mn and its uptake which was reflected during the observations in experiment-IV and it can be so strong that it produces toxicity in sensitive crops (Tisdele et al, 1995). Similarly phosphatic fertilizers have also about 40-2000 ppm Mn (Pendias and Pendias, 1992) which can be a good source of Mn as noted in experiment-III. As pointed out earlier Mn

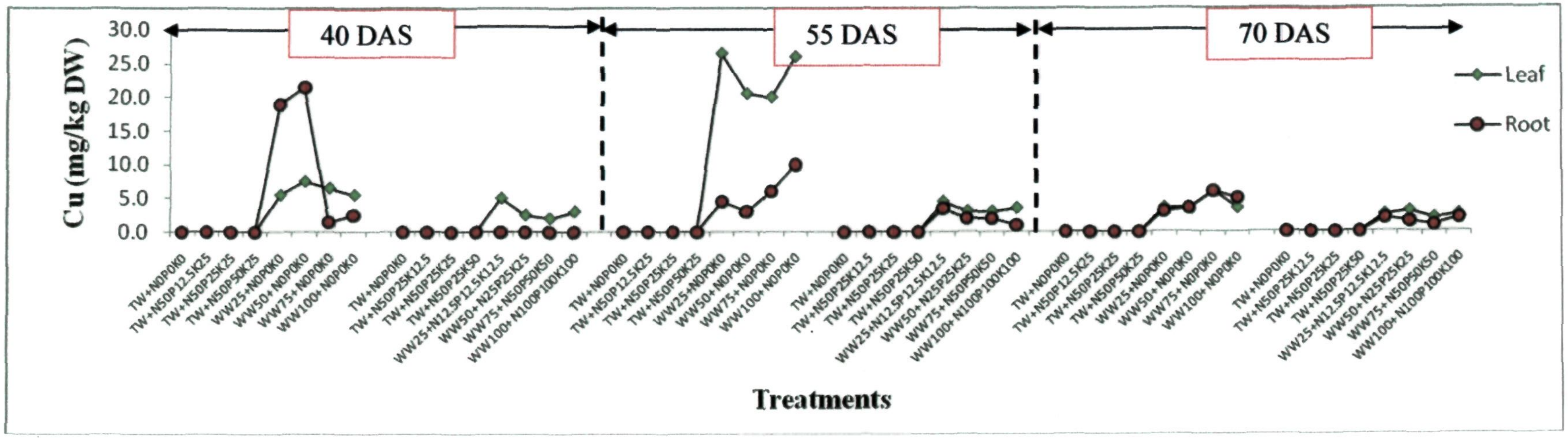



Fig: 19 a, Copper concentration in root and leaf in experiments I-II at three stages

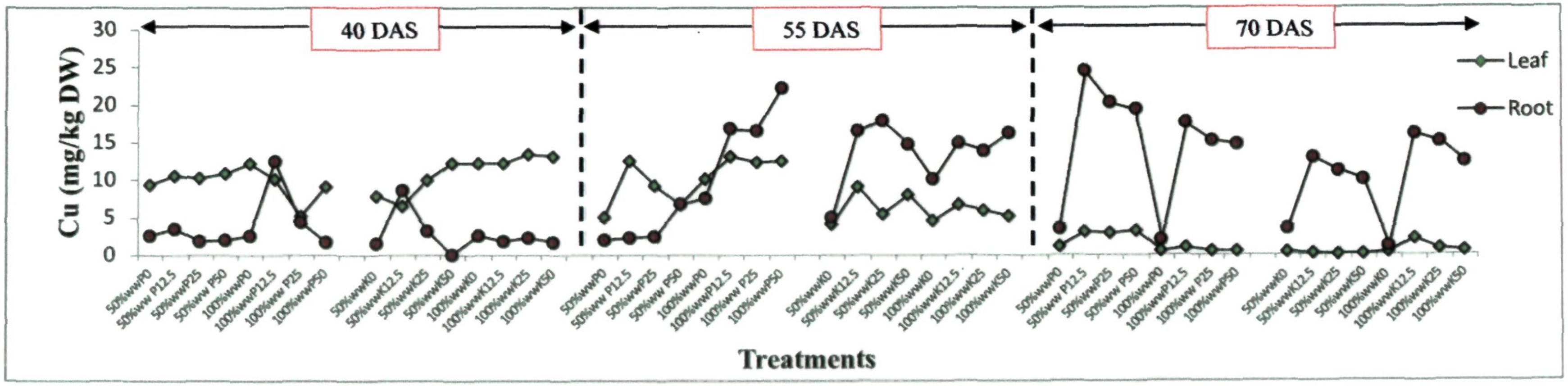



Fig: 19 b, Copper concentration in root and leaf in experiments III-IV at three stages

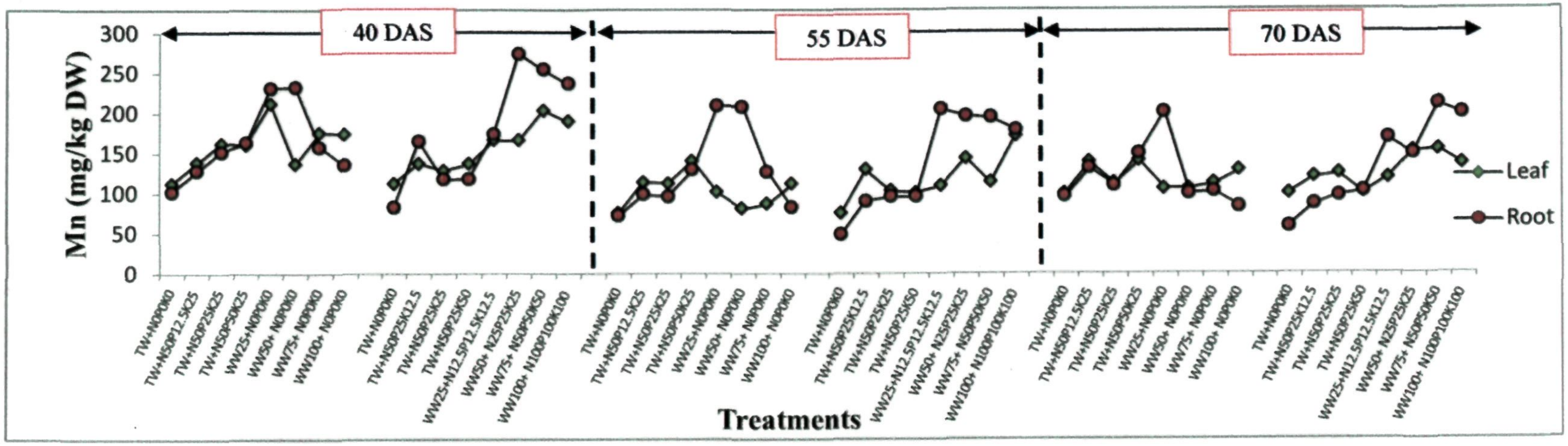



Fig: 20 a, Manganese concentration in root and leaf in experiments I-II at three stages

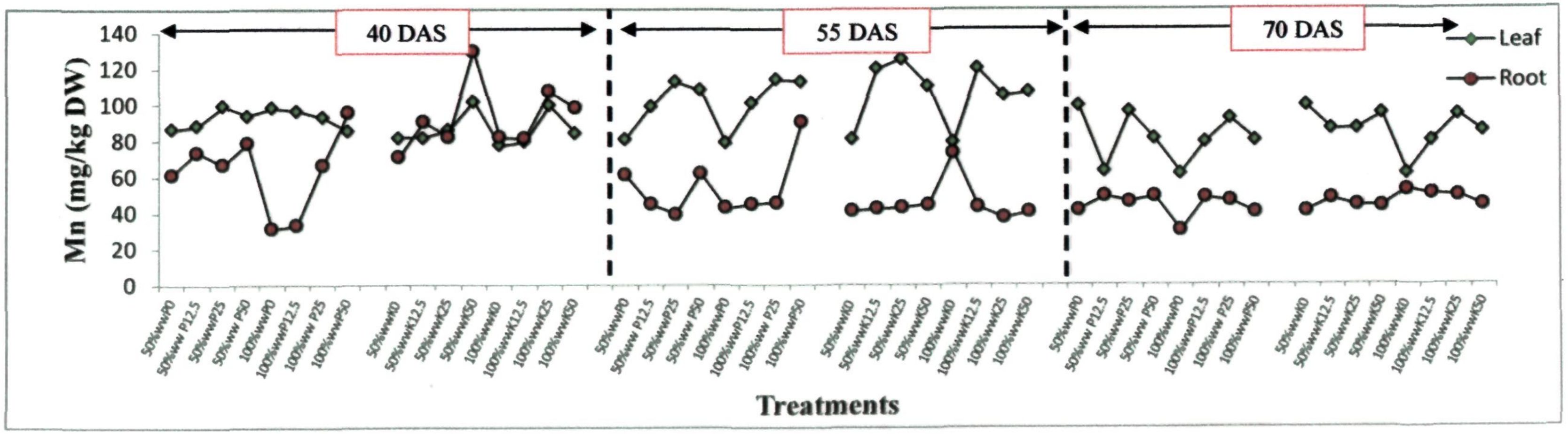



Fig: 20 b, Manganese concentration in root and leaf in experiments III-IV at three stages contents were also more in wastewater than in tap water and it shows a remarkable variation depending upon the plant species, stage of growth, different organs as well as different sources. The TF values in general were >1 in all experiments although it reverse in some cases. It may be because Mn concentration fluctuates greatly within the plant parts and within the vegetative period. It is not only an effect of plant characteristics but also of the pool of available Mn which is controlled basically by soil properties. Although it is relatively immobile like iron but its mobility varies depending upon its supply.

**5.5.7 Zinc:** Its normal concentration range is 25 to 150 ppm in plants and its deficiency is usually associated with concentrations of less than 20 ppm, and toxicities with 400 ppm or more and in our study it was from 40-220 mg/kg (Fig: 21 a, b). In experiment-I and II its concentration was more in wastewater than the tap water because of its presence in wastewater and in N, P fertilizers. This may also be because of soluble forms of Zn are readily available to plants and its uptake has been reported to be linear with concentration in the nutrient solution and in soils as provided under the conditions of present study (Fig 21 a, b). The TF values was generally <1 in all the experiments. Therefore, the roots often contained much more Zn than the tops, particularly when plants are grown in Zn rich conditions. With luxury levels of soil Zn, this element may be translocated from the roots and accumulated by the tops of the plant. Therefore, the rate of Zn absorption differs greatly among both plant species and growth medium.

## 5.6 HEAVY METALS ACCUMULATION

The order of heavy metal accumulation was Fe >Mn >Zn >Ni >Cr >Cu >Cd. These results were more or less in agreement with the studies undertaken by Grytsyuk et al, (2006), Zheng et al, (2007), Arora et al, (2008), and Khan et al, (2008), while working on various vegetables including turnip. In our study Fe concentration was maximum because of its high concentration in soil as well as in wastewater compared to other elements. It was followed by Mn. In general higher concentration of Mn may be because it is easily taken up by the plants when it occurs in soluble form. Like Fe chelated Zn is important for its transport to root surface for uptake and its availability predominantly governed by the pH and adsorbed Zn on soil colloids. It may also be observed that primary and secondary minerals dissolve initially provide Zn to the soil

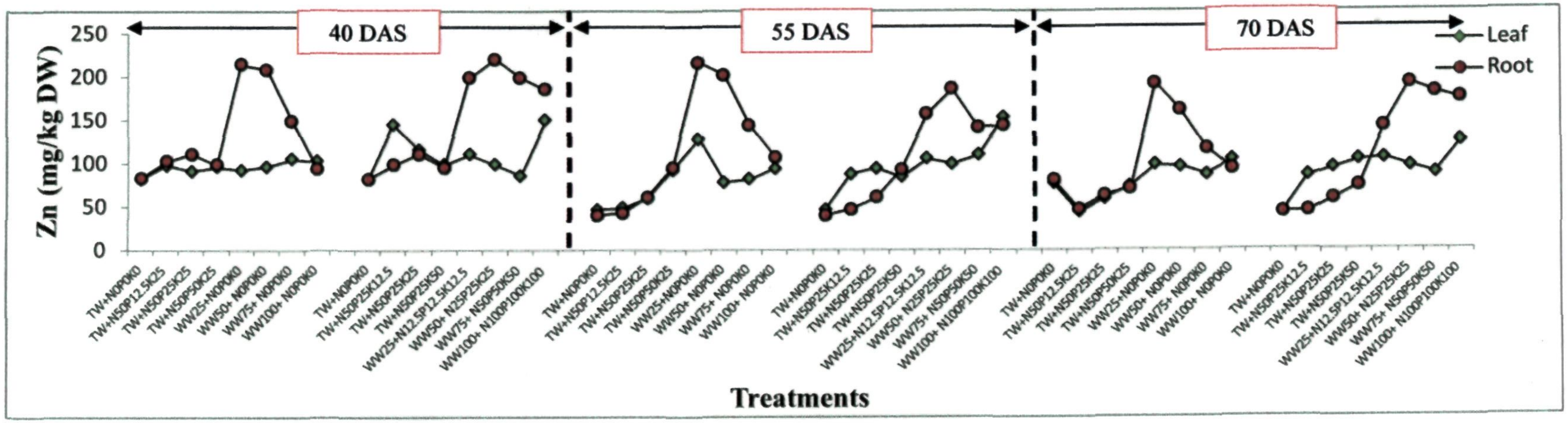



Fig: 21 a, Zinc concentration in root and leaf in experiments I-II at three stages

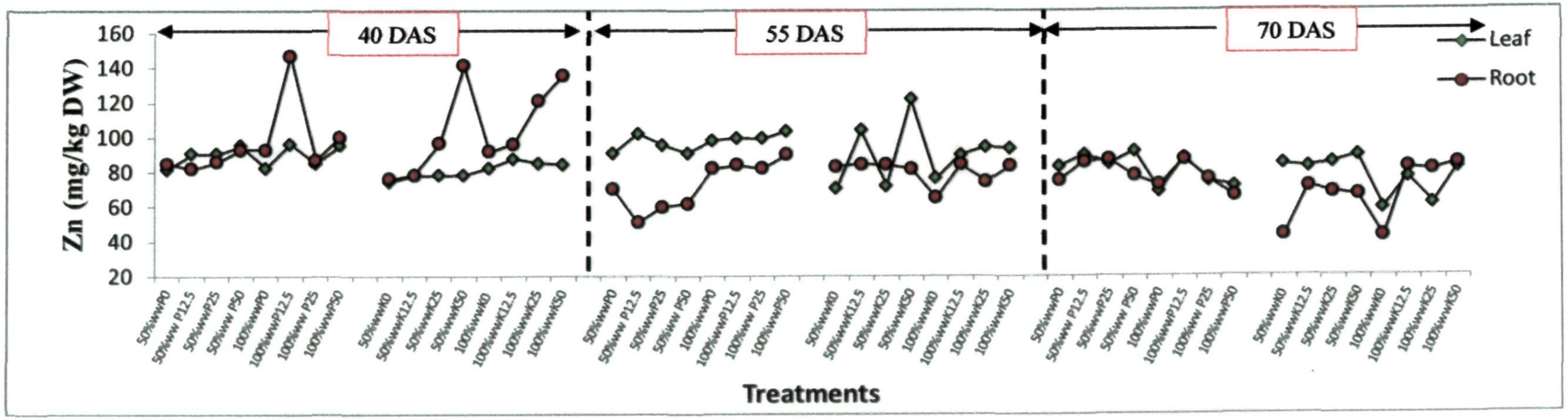



Fig: 21 b, Zinc concentration in root and leaf in experiments III-IV at three stages solution for its availability which may also be responsible for comparatively higher Zn content. Zn was followed by Ni as sewage sludge may result in higher levels of Ni. In addition it is also readily taken up by most plant species (Havlin et al, 1999). Among the seven trace elements comparatively lower concentration of Cu after Cd may be due to their greater dependability on solubility and soil pH.

Most of the heavy metals decreased with growth in both organs. This decreasing trend can be ascribed to the exponential increase in growth and as a result of dilution with growth effect even higher quantities of elements appear to be less when expressed on per unit basis (Moorby and Besford, 1983). However, Ni in leaf and Cr, Cu in root were increased with growth (Experiment III, IV) which may be because of the selective properties of ion absorption in plants (Devlin and Witham, 1986). In addition, phytoavailability of metals also depends on the form of the metal ion and on the plant species tested. However, even if using the same species the uptake by plants does not necessarily correlate with the bioavailable metal concentration in the soil or the total metal concentration. This is probably due to the genotype with inherent capability of different metal uptakes as pointed out above in case of Ni, Cr, and Cu. It may also be added that plants also differ in their transport of ions resulting in differences in concentration in plant parts (Greger, 2004) as observed in the present study also where the heavy metals fluctuated between the root and leaf depending upon the growth stage, availability of individual element and also their interactions.

While considering the 34 ML/d wastewater in many cases heavy metal concentration was more in plants grown under 50%ww than the 100%ww in case of leaf (Table 39, 40, 41, 42, 43, 44, 45, 52, 55, 56, 57, 58) and in case of root (Table 41, 42, 43, 44, 45, 54, 55, 58) in experiment-III and IV. This was not surprising because metal uptake may differ in relation to external concentration and genotypes. It may also be pointed out that uptake is not linear in relation to increase in wastewater concentration in many cases which may be because metals are bound in the tissues causing saturation which is governed by the rate at which the metal is conducted away. Therefore, the uptake efficiency is more at low concentration which was observed in solution culture (Greger et al, 1991) as well as in soil (Greger, 1997) for Cd. It may be because of low metal concentration per absorption area giving low competition between the ions at the uptake sites while the opposite occurs at high concentration.

**Table: 59 Range of heavy metals present in plant parts in 38 and 34 ML/d waste water.**

| Heavy Metals | Range (mg/Kg DW) 38 ML/d Experiment I and II | | Range (mg/Kg DW) 34 ML/d Experiment III and IV | | Toxic or excessive limit for plants Pendias and Pendias (1992) | Markert. 1994 |
|---|---|---|---|---|---|---|
| | Root | Leaf | Root | Leaf | | |
| **Cd** | 1.5-25 | 0.5-7.8 | 1.0-16.3 | 1.0-5.3 | 5-30 | 0.05 |
| **Cr** | 0-46 | 0-0 | 0-45 | 0-50 | 5-30 | 1.5 |
| **Ni** | 10-132 | 12-110 | 17-136 | 0-131 | 10-100 | 1.5 |
| **Fe** | 550-1835 | 115-1255 | 263-1108 | 445-1251 | -- | 150 |
| **Cu** | 0-22 | 0-29 | 0-25 | 0-14 | 20-100 | 10.0 |
| **Mn** | 48-274 | 0-212 | 30-130 | 62-126 | 300-500 | 200 |
| **Zn** | 40-220 | 43-152 | 42-147 | 58-122 | 100-400 | 50.0 |

The table-59 indicates the range of heavy metals in turnip (root and leaf) in all the experiments together. We conclude from this table that all the heavy metals in this study were generally found in the range of more or less excessive levels (Pendias and Pendias, 1992) except Mn. However, when these values were compared with Markert 1994, most of the values were in excessive range. Since different plant species have different uptakes it is difficult to know whether the uptake is low or high. Therefore Markert, (1994) tried to give values of the metal concentration of a normal plant with which the uptake in a species could be compared.

## 5.7 CONCLUSIONS

1. Analysis of the wastewater revealed its suitability for the irrigation as most of the values for the analyzed parameters were within the permissible limits of FAO/WHO/Pescod. Irrigation water having conductivity between 750-2250 µmhos/cm is classified as medium to high saline and comparatively safe for irrigation because the EC of the wastewater studied was 750-1890 µmhos/cm.
2. Heavy metals, Cd, Cr, Ni, Fe, Cu, Mn and Zn were within the permissible limits for irrigation water.
3. The microbiological examination of the wastewater revealed the presence of some pathogenic micro-organisms therefore, the growers may be warned to be careful during irrigation operation.
4. Among the wastewater concentrations 100%ww of 38 ML/d showed maximum plant fresh weight, leaf fresh weight, root fresh weight, root diameter, and plant height. Application of 100%ww significantly enhanced growth parameters over 25%, 50%, 75%ww and TW, (Experiment-I) therefore, there is no need of its dilution.
5. Utility of 38 ML/d wastewater for crop growth can be attributed to the fact that it contained sufficient amount of essential and beneficial nutrients thus minimizing the inorganic fertilizer requirement coupled with its alternate disposal on land through agriculture and also saving the depleting resources of fresh water (Experiment-I).
6. Among P doses, $P_{25}$ gave maximum values and $P_{50}$ was excessive for most of the growth parameters including plant fresh weight, leaf fresh weight, root diameter, and plant height while $P_{12.5}$ was deficient (Experiment-I).
7. Among the wastewater concentrations of 38 ML/d with NPK fertilizers 50%ww$N_{25}P_{25}K_{25}$ showed maximum plant fresh weight, leaf fresh weight, and plant height. Thus proving to be the best combination as fertilizer doses were sufficiently lowered due to wastewater (Experiment-II).
8. While among the tap water treatments TW$K_{50}$ proved best for increasing plant fresh weight, plant height, and leaf fresh weight whereas $K_{12.5}$ was deficient (Experiment-II).
9. 50%ww of 34 ML/d proved best over 100%ww therefore it can be used after dilution. The combination 50%ww$P_{12.5}$ proved beneficial in enhancing the

growth which was at par with 50%ww$P_{25}$ indicating usefulness of wastewater where 12.5 kg P/ha could be saved. (Experiment-III).

10. 50%ww of 34 ML/d also proved best with $K_{12.5}$, therefore, the combination 50%ww$K_{12.5}$ and the combination proved effective for plant fresh weight, root fresh weight and leaf fresh weight giving maximum values and it was at par with 50%ww$K_{25}$ indicating the economy of 12.5 kg K/ha (Experiment-IV).
11. In the leaf and root samples all heavy metal concentrations were more than the toxic limits except Mn. In leaf, Cd, Cr, Cu and Zn concentration was below the toxic level at harvest stage in 34 ML/d wastewater.
12. Plant fresh weight, root fresh weight, leaf fresh weight, and root diameter increased with increasing age of the plants.
13. The trend of heavy metal accumulation was in the order Fe >Mn >Zn >Ni >Cr >Cu >Cd which incidentally indicating lower concentration of the two heavy metals (Cu, Cd) which are not essential.
14. The best harvest stage of turnip was 70 days after sowing.
15. The concentration of heavy metals was at excessive levels at 40 and 55 DAS, while at 70 DAS metal concentration was low.
16. The translocation factor for most of the heavy metals from root to leaf was <1 showing more concentration in root except Fe and Mn, concentration was generally more in leaf.
17. Among the three waters the heavy metal concentration was more in 38 ML/d wastewater followed by 34 ML/d and TW.
18. Some crucifers are reported to be heavy metal harvesters. Therefore in the present study, since root has accumulated excessive levels of heavy metals, it may be treated as heavy metal accumulator. Under this situation roots may be discarded at least for few years and only leafy part which has also nutritive value and low heavy metal concentration as pointed out earlier may be recommended for consumption to local farmers.

## 5.8 PROPOSAL FOR FUTURE STUDIES

Observations recorded during two years have helped in understanding the utility of the wastewater in crop production however, still there remain some areas where work can further be undertaken.

1. Experiments should be repeated in the farmer's field to confirm the findings of pot experiments.
2. Few more heavy metals like As and Pb should also be tested in soil, water, and parts.
3. Variations of nitrogen doses and more microbiology of wastewater and its effect on plants should be tested.
4. Heavy metal removal by the plants and health risk should be tested.
5. The quality of turnip like carbohydrates, proteins in root and leaf should also be recorded in any future work.

# CHAPTER 6

# SUMMARY

Before the beginning of chapter I, list of tables, and list of figures was given for the convenience of the reader.

Chapter I (Introduction) included the significance of wastewater management through agriculture, importance of the plant nutrition and the crop to be studied was explained.

Chapter II contained the review of literature on the effect of wastewater on turnip, other vegetables, other crops and heavy metal accumulation and their removal.

In Chapter III the methods and techniques employed in four pot experiments conducted during the 'rabi' seasons of 2006-2008 were explained. Agroclimatic conditions of Roorkee, analysis of tap water, waste water and soil including heavy metals and the microbiology of the wastewater were incorporated.

Chapter IV comprises of the experimental results which were presented in tables 13-58 and summarized below.

Experiment-I was conducted on turnip during the 'rabi' season of 2006-2007 to study the comparative effect of four concentration of 38 ML/d wastewater i.e. 25%ww, 50%ww, 75%ww and 100%ww and the tap water with different doses of phosphorus ($P_0$, $P_{12.5}$, $P_{25}$, $P_{50}$) with a uniform basal dose of $N_{50}$ and $K_{25}$. 100%ww proved beneficial for most parameters studied including plant fresh weight, root fresh weight, leaf fresh weight, leaf number and root diameter. Among different doses $P_{25}$ proved optimum as $P_{50}$ was excessive and $P_{12.5}$ was deficient and among interactions $TWP_{25}N_{50}K_{25}$ proved optimum.

Experiment-II (2006-2007) was conducted simultaneously with Experiment-I to study the effect of the same 38 ML/d wastewater with different concentrations in presence of different doses of NPK (12.5, 25, 50 and 100 kg/ha NPK) and four levels of potassium i.e. $K_0$, $K_{12.5}$, $K_{25}$ and $K_{50}$ given with tap water alone with a uniform basal dose of $N_{50}$ and $P_{25}$. Among the wastewater concentrations with NPK fertilizers $50\%wwN_{25}P_{25}K_{25}$ showed maximum plant fresh weight, leaf fresh weight, and plant height. Thus proving to be the best combination as fertilizer doses were sufficiently lowered due to wastewater. While among the tap water treatments $K_{50}$ proved best for increasing plant fresh weight, plant height, and leaf fresh weight and $K_{12.5}$ was found to be deficient.

Experiment-III (2007-2008). In this experiment the performance of the same variety of turnip was studied with two levels of waste water i.e. 50%ww and 100%ww and four levels of phosphorus ($P_0$, $P_{12.5}$, $P_{25}$, $P_{50}$) with a uniform basal dose of $N_{50}$ and $K_{25}$. In this study 34 ML/d wastewater was used in place of 38 ML/d wastewater. 50%ww proved better than 100%ww and improved results were given by the interaction 50%ww$P_{12.5}$ which proved beneficial in enhancing the growth which was at par with 50%ww$P_{25}$ indicating the usefulness of wastewater where 12.5 kg P could be saved.

Experiment-IV (2007-2008) was conducted simultaneously with experiment-III. In this experiment again 34 ML/d, waste water was used with two concentration of waste water i. e. 50% and 100% with different doses of potassium ($K_0$, $K_{12.5}$, $K_{25}$ and $K_{50}$) and a uniform basal dose of $N_{50}$ and $P_{25}$. Among interaction 50%ww$K_{12.5}N_{50}P_{25}$ was more effective interaction for fresh weight of root and leaf and it was at par with higher dose of $K_{25}$ (50%ww$K_{25}N_{50}P_{25}$).

This observation indicated the possibility of inorganic fertilizer saving if the wastewater is used for irrigation. Since 50%ww proved best therefore dilution of waste water was required in case of 34 ML/d while 38 ML/d can be used without dilution. In all the experiments heavy metal concentration was found more than the toxic or excessive levels except Mn. Although heavy metals were found in permissible limits in wastewater but due to regular watering heavy metal concentration has gone up to excessive level. Metal concentration was comparatively more in 38 ML/d wastewater treatments.

In Chapter V the data was discussed in the light of the research work carried out by other workers on the similar aspects and correlations of some parameters with root, and leaf growth was also undertaken. In the end, conclusions were drawn and finally some suggestions were also incorporated for the future work. The present chapter gives chapter wise detail of the entire study. It followed by relevant references cited in the text and an appendix of the reagents used during the experimental work.

# BIBLIOGRAPHY


**Abdel-Ghani, N.T., and Elchaghaby, G.A., (2007).** Influence of operating conditions on the removal of Cu, Zn, Cd and Pb ions from wastewater by adsorption. *J.Environ. Sci. Tech.*, **4**: 451-456.

**Abia, A.A. and Igwe, J.C. (2005).** Sorption kinetics and intraparticulate diffusivities of Cd, Pb and Zn ions on maize cob. *Afr. J. Biotechnol.*, **4**: 509-512.

**Adjei, M.B. and Rechcigl, J. E. (2002).** Bahiagrass production and nutritive value as affected by domestic wastewater residuals. *Agron. J.*, **94:** 1400-1410.

**Ahmad, I., Ali, S. and Jan, M.R. (2000).** Physico-chemical analysis of fertilizer industry effluent and its effects on crop plants. *Pakistan J. Scient. Indus. Res.*, **43**: 83-89.

**Ajmal, M. and Khan A.U. (1984b).** Effects of vegetable ghee manufacturing effluent on soil and crop plants. *Environ. Poll.*, **34:** 364-379.

**Ajmal, M. and Khan, A.U. (1983).** Effects of sugar factory effluent on soil and crop plants. *Environ. Poll.*, **30**: 135-141.

**Ajmal, M. and Khan, A.U. (1984a).** Effects of brewery effluent on agricultural soil and crop plants. *Environ. Poll.*, **33**: 341-351.

**Ajmal, M. and Khan, A.U. (1985a).** Effects of textile factory effluent on soil and crop plants. *Environ. Poll.*, **37**: 131-148.

**Ajmal, M. and Khan, A.U. (1985b).** Effects of electroplating factory effluent on the germination and growth of hyacinth bean and mustard. *Environ. Res.*, **38:** 248-255.

**Ajmal, M., Khan, M.A. and Nomani, A.A. (1984).** Effects of industrial dairy processing effluent on soil and crop plants. *Enviro. Poll.*, **33:** 97-106.

**Al-lahham, O., Assi, N.M.E. and Fayyad, M. (2007).** Translocation of heavy metals to tomato (*Solanum lycopersicom* L.) fruit irrigated with treated wastewater. *J. Sci. Hort.*, **113**: 250-254.

**Angelova, V., Ivanova, R., Delibaltova, V., and Ivanov, K., (2004).** Bio-accumulation and distribution of heavy metals in fibre crops (*flax, cotton and hemp*). *J. Ind. Crops Prod.*, **19:** 197-205.

**Anjana, S. and Rao, C.L.S.N. (1996).** Effect of gelatin factory effluents on seed germination and seedling growth of some important crop plants. *J. Environ. Biol.*, **17**: 143-148.

**Anonimous, (2008).** Available from: http://www.hort.purdue.edu/newcrop/afcm/turnip.html and http://hungryzone.com/index.php/detailed-health-tip-article/ 48/Benefits-of-Turnip

**APHA, (1998).** *Standard Methods for the Examination of Water and Wastewater,* 20th edition, American Public Health Association, Washington, DC.

**Arora, C.L. and Chibba, I.M. (1992).** Influence of sewage disposal on the micronutrient and sulphur status of soils and plants. *J. Indian Soc. Soil Sci.*, **40**: 792-795.

**Arora, K.R., (2000).** *Soil Mechanics and Foundation Engineering.* 5thEd. Standard Publishers Distributors.

**Arora, M., Kiran, B., Rani, S., Rani, A., Kaur, B. and Mittal, N. (2008).** Heavy metal accumulation in vegetables irrigated with water from different sources. *J. Food Chem.* **111**: 811-815.

**Avdeeva, T.A. and Andreeva, T.F. (1974).** Effect of conditions of phosphorus nutrition on photosynthesis and activity of carboxylating enzymes in bean and corn plants. *Soviet Plant Physiol.* **21**: 753-757. In: *The role of Phosphorus in Agriculture*, 1980. p. 574. F.E. Khasawneh, E.C. Sample and E.J. Kamprath (Eds.) Publ. by ASA-CSSA-ASSA, Madison, WI, USA.

**Ayers, R.S. and Westcot, D.W. (1994).** Waste quality for agriculture: FAO irrigation and drainage. Paper 29. Rev., 1:1-130.

**Aziz, O. and Inam, A. (1995).** Post irrigation effect of sewage on some crop plants and agriculture soil. *Indian J. Environ. Prot.*, **15**: 197-200.

**Aziz, O., Inam, A. and Siddiqi, R.H. (1994).** Impact of treated oil refinery effluent on crop productivity and agricultural soils. *Indian J. Environ. Hlth.*, **36**: 91-98.

**Aziz, O., Inam, A. and Tarannum, K. (1993a).** Effect of treated refinery wastewater on nitrate reductase activity of *Vigna radita* L. *Geobios.*, **20**: 14-16.

**Aziz, O., Inam, A., and Samiullah (1999).** Utilization of petrochemical industry waste water for agriculture. *J. Water Air Soil Pollut.*, **115:** 321-335.

**Aziz, O., Inam, A., Samiullah and Siddiqi, R.H. (1996a).** Long term effects of irrigation with petrochemical industry wastewater. *J. Environ. Sci. Hlth.*, **31**: 2595-2620.

**Aziz, O., Manzar, M. and Inam, A. (1995).** Suitability of petrochemical industry wastewater for irrigation. *J. Environ. Sci. Hlth.*, **30**: 735-751.

**Aziz, O., Samiullah., Inam, A. and Khan N.A. (1993b).** Effect of treated Mathura oil refinery effluent on the performance of lentil (*Lens culinaris* L. Medic.). *Chem. Environ. Res.*, **2**: 295-299.

**Aziz., O., Khan, N.A., Inam, A. and Samiullah, (1996b).** Performance of berseem (*Trifolium alexandrium* L.) under treated refinery wastewater *Poll. Res.*, **15**: 177-180.

**Azmat, R., Uzma., and Uddin F. (2007).** Biosorption of toxic metals from solid sewage sludge by marine green algae. *J. Plant Sci.*, **6**:42-45.

**Bagchi, D.K. (1982).** Nirtogen nutrition and extracted leaf protein yields of four crops in Genetic alluvium soils. In: *Frontiers of Research in Agriculture*. pp 497-505, S.K. Roy (ed.). Indian Statistical Institute, Calcutta.

**Basker, M., Kayalvizhi, C. and Bose, M.S.C. (2003).** Ecofriendly utilization of distillery effluent in agriculture- a review. *Agric. Rev.*, **24**: 16-30.

**Bear, F.E., (1964).** *Chemistry of the Soil.* 2nd Ed. Oxford and IHB Publishing Company Pvt. Ltd. New Delhi, Bombay, Calcutta.

**Behera, P.K., (2006).** *Soil and Solid waste Analysis.* A laboratory manual. Dominant publishers and distributors. New Delhi.

**Bera, A.K. and Saha, A. (1998).** Effect of tannery effluent on seed germination and early seedling growth of pigeonpea and rice. *Seed Res.*, **26**: 34-38.

**Bhardwaj, R.M. (2005).** Water quality monitoring in India-Achievements and constrains, IWG Environ. Joint Work Session on Water Statistics, Vienna, 20-22 June.

**Bidwell, R.G.S. (1979).** *Plant Physiology.* 2nd Ed. pp. 260-261, Macmillan Publishing Co., New York.

**Bishnoi, S. and Gautam, D.D. (1991).** Effect of dairy effluent on seed germination and seedling growth of some crop plants. *Int. J. Ecol. Environ. Sci.*, **17**: 67-71.

**Bowen, H.J.M. (1979).** *Environmental Chemistry of the Elements*. Academic Press, New York. 333.

**Bradley, G.A., Sistrunk, W.A., Baker, E.C., Cash, J.N. and Motes, D.R. (1973)**. Plant spacing and nitrogen fertilization for turnip greens. Ark. Farm Res., **22**: 11.

**Burun, B., Tuna, A.L.,Yokas, I. and Ege, H. (2006).** Some soil properties of lime stabilized urban wastewater and effects on barley's yield and mineral matter content. *J. Agron.*, **5**: 37-44.

**Cataldo, D.A., Garland, T.R. and Wildung, R.E. (1978).** Nickel in plants. *Plant Physiol.*, **62**, 1. 563; 11, 566.

**Chandra, R., Bharagava, R.N., Yadav, S. and Mohan, D. (2009).** Accumulation and distribution of toxic metals in wheat (*Triticum aestivum* L.) and Indian mustard (*Brassica campestris* L.) irrigated with distillery and tannery effluents. *J, Hazard. Mater.* **162**: 1514-1521.

**Chaney, R.L. and Hornick, S. B. (1977).** Accumulation and effects of cadmium on crops, paper presented at Int. Cadmium Conf., San Francisco, 31 January, 125.

**Chauhan, D.V.S. (1968).** *Vegetable Production in India.* 2ndEd. p.210, Ram Prasad and sons, Agra.

**Chow, K.K., Wang, J.Y., Tay, J.H., Bar, T.A. and Plaut, Z. (2001)**. Hydroponic cultivation of leafy vegetables in primary and secondary municipal wastewater. Proceeding of the World Congress on Soilless Culture: agriculture in the coming millennium Ma'ale Hachamisha, Acta Hort., **554**, 139-146. (Cited from CAB Abstr. 2000/08-2002/07.

**Cisneros, B.J. Orhon, D., Jimenez, B., Tilche, A. and Buitron, G. (1995)**. Wastewater reuse to increase soil productivity. *Water Sci. Technol.*, **32**: 173-180.

**Court, M.N., Stephen, R.C. and Ward, J.S. (1964)**. Toxicity as a cause of the inefficiency of urea fertilizer. *Exp. J. Soil Sci.* **15:** 49-65. In: *Nitrogen in Crop Production.* 1984. (Eds. Goyal. S. S. and Huffaker, R.L.). p.102 ASA-CSSA-SSSA, Madison, WI., USA.

**Cui, L.H., Luo, S.M., Zhu, X.Z. and Liu, Y.H. (2003).** Treatment and utilization of septic tank effluent using vertical flow constructed wetlands and vegetable hydroponics. *J. Environ. Sci.*, **15:** 75-82.

**Del Welle, C.G. and Harmon, S.A. (1970).** Influence of seedling rate, source and level of nitrogen on yield, colour, leaf blade weight, and nitrogen content of turnip greens. *J. Amer. Soc. Hort. Sci.*, **95**: 62-64.

**Demirezen, D. and Aksoy, A. (2004).** Accumulation of heavy metals in *Typha angustifolia* (L.) and *Potamogeton pectinatus* (L.) living in Sultan Marsh (Kayseri, Turkey). *J. Chemosphere.*, **56:** 685-696.

**Deng, H., Ye, Z.H. and Wong, M.H. (2004).** Accumulation of lead, zinc, copper and cadmium by 12 wetland plant species thriving in metal-contaminated sites in China. *J. Environ. Poll.,* **132**: 29-40.

**Devlin, R.M. and Witham, F.H. (1986).** *Plant Physiology.* 4$^{th}$Ed. C.B.S. Publishers and Distributors, Shahadra, New Delhi.

**Dietz, K.J. and Foyer, C. (1986).** The relationship between phosphate status and photosynthesis in leaves: Reversibility of the effects of phosphate deficiency on photosynthesis. *Planta* **167**: 376-381.

**Eid, M.A. and Shereif, M.M. (1996).** Effect of wastewater irrigation on growth and mineral contents of certain crops (green house conditions). *Fourth National Congress on Pollution Control of Agricultural Environment.* Egypt. *J. Soil Sci.*, **36**: 109-118.

**Elsokkary, I.H. and Sharaf, A.I. (1996).** Enrichment of soils and plants irrigated by wastewater by zinc and cadmium. *Egypt. J. Soil Sci.*, **36**: 219-232.

**Emonger, V.E. and Ramolemana, G.M. (2004).** Treated sewage effluent (water) potential to be used for horticultural production in Botswana. *J. Phys. Chem. Earth.*, **29**: 1101-1108.

**Emongor, V.E., Khonga, E.B., Ramolemana, G.M., Marumo, K., Machacha, S. and Motsamai, T. (2005).** Suitability of treated secondary sewage effluent for irrigation of horticultural crops in Botswana. *J. Applied Sci.* 5: 451-454.

**Engeistad, O.P. and Terman, G.L. (1967).** Importance of water solubility of phosphorus fertilizers. Fert. News, 7: 2-12.

**Fasciolo, G.E., Meca, M.I., Gabriel, E. and Morabito, J. (2002).** Effects on crops of irrigation with treated municipal wastewaters. *J. Water Sci. Technol.*, **45:** 133-138.

**Fernandes, F., Valentao, P., Sousa, C., Pereira, J.A., Seabra, R.M. and Andrade, P.B. (2007).** Chemical and antioxidative assessment of dietary turnip (*Brassica rapa* var. *rapa* L.). *J. Food Chem.*, **105**: 1003-1010.

**Fredeen, A.L., Raab, T.K., Rao, I.M. and Terry, N. (1990).** Effects of phosphorus nutrition on photosynthesis in *Glycine max.* (L.) Merr. Planta **181**: 399-405.

**Ganguly, A.K. (1951).** *J. Phys. Colloidal Chem.*, **55**: 1417-1428.

**Ghosh, A.K., Kumar, P. and Roy, N.P. (1999).** Physico-chemical analysis of distillery effluent and their effect on germination of some legumes. *Neo Botanica,* 7: 27-32.

**Gill, H.S. (1979).** Pusa Swarnima a turnip variety of promise. *Indian Hort.*, **24**: 7-8.

**Gong, P., Wilke, B.M., Strozzi, E. and Fleischmann, S. (2001).** Evaluation and refinement of a continuous seed germination and early seedling growth test for the use in the ecotoxicological assessment of soils. *J. Chemosphere.*, **44**: 491-500.

**Goswami, M. and Naik, M.L. (1992).** Effect of a fertilizer effluent on chlorophyll contents of *Cyamopsis tetragonoloba* Taub. *J. Environ. Biol.*, **13**: 169-174.

**Goyal, S., Chander, K. and Kapoor, K.K. (1995).** Effect of distillery wastewater application on soil microbiological properties and plant growth. *Environ. Ecol.*, **13**: 89-93.

**Greenwood, D.J., Stone, D.A. and Karpinets, T.V. (2001).** Dynamic model for the effects of soil P and fertilizer P on crop growth, P uptake and soil P in arable cropping: Experimental test of the model for field vegetables. *Annals Bot.*, **88:** 293-306.

**Greger, M. (1997).** Willow as phytoremediator of heavy metal contaminated soil. Proceedings of the 2nd international conference on element cycling in the environment, Warsaw, pp 167-172.

**Greger, M. (2004).** Metal Availability, Uptake, Transport and Accumulation in Plants. In: *Heavy Metal Stress in Plants.* 2nd Ed. p. 462. Narosa publishing house New Delhi, Chennai, Mumbai, Kolkata).

**Greger, M., Brammer, E., Lindberg, S., Larsson, G. and Idestam-Almquist, J. (1991).** Uptake and physiological effects of cadmium in sugar beet (*Beta vulgaris*) related to mineral provision. *J. Exp. Bot.*, **42**: 729-737.

**Grytsyuk, N., Arapis, G., Perepelyatnikova, L., Ivanova, T. and Vynogradska, V. (2006).** Heavy metals effects on forage crops yield and estimation of elements accumulation in plants as affected by soil. *J. Sci. Total Environ.*, **354**: 224-231.

**Gupta, P.K. (2004).** Soil, plant, water and fertilizer analysis. *Agrobios*. Jodhpur, India.

**Guttormsen, G., Singh, B.R. and Jeng, A.S. (1995).** Cadmium concentration in vegetable crops grown in a sandy soil as affected by Cd levels in fertilizer and soil pH. *J. Fertilizer Res.*, **41**: 27-32.

**Hach Manual (1999).** *Digesdahl Digestion Apparatus*. Models 23130-20. Instrument Manual. Hach company USA.

**Haghiri, F.E. (1974).** Plant uptake of cadmium as influenced by cation exchange capacity, organic matter, zinc, and soil temperature. *J. Environ. Qual.*, **3:** 180-182.

**Hammet, L.K., Miller, C.H., Swallow, W.H. and Harden, C. (1984).** Influence of N source, N rate and K rate on the yield and mineral concentration of sweet potato. J. *Amer. Soc. Hort. Sci.*, **109**: 294-298.

**Havlin, J.L., Beaton, J.D. Tisdale, L.T. and Nelson W.L. (1999).** *Soil Fertility and Fertilization; An Introduction to Nutrient Management.* 6th Ed. Pearson Education (Singapore) Pvt. Ltd.

**Hopkins, W.G. and Huner, N.P.A. (1995).** *Introduction to Plant Physiology*. 4th Ed. Printed in the United States of America.

**Horsfall, M.J., Abia, A.A. and Spiff, A.I. (2003).** Removal of Cu (II) and Zn (II) ions from wastewater by cassava (*Manihot esculenta* Cranz) waste biomass. *African J. Biotechnol.*, **2**: 360-364.

**Igwe, J.C., Abia, A.A., and Ibeh, C.A., (2008).** Adsorption kinetics and intraparticulate diffusivities of Hg, As and Pb ions on unmodified and thiolated coconut fiber. *Int. J. Environ. Sci. Tech.*, **5**: 83-92.

**Inam, A., Aziz, O. and Tarannum, K. (1993).** Impact of Mathura oil refinery effluent on seedling emergence of triticale and wheat. *Geobios*, **20:** 16-18.

**Iqbal, S., (2009).** Effect of waste water on growth and productivity of chilli. M. Phil. dissertation. Aligarh Muslim University, Aligarh, India.

**Islam, M.A. and Rashid, M.M. (1973).** Tolerance of different winter vegetables to the foliar application of urea. *Bangladesh Horticulture*, **1**: 12-15.

**Jabeen, S., and Saxena, P.K. (1990).** Effect of industrial effluent on growth behavior of *Pisum sativum*. *Geobios*, **17**: 197-201.

**Jacobs, J. and Ward, G. (2006)**. Effect of different rates of dairy effluent on turnip DM yields and nutritive characteristics. Proceedings of the 13$^{th}$ Australian Agronomy Conference 10-15 September 2006.

**Jacobs, J.L., Ward, G.N. and Kearney, G. (2004).** Effects of irrigation strategies and nitrogen fertilizer on turnip dry matter yield, water use efficiency, nutritive characteristics and mineral content in western Victoria. *Australian J. Exp. Agric.*, **44**: 13-26.

**Jacobs, J.L., Ward, G.N., and McDowell, A.M., (2006).** Management techniques and turnip variety effects on turnip yield in western Victoria. Proceedings of the 13$^{th}$ Australian Agronomy Conference 10-15 September 2006.

**Jambhulkar, H.P. and Juwarkar A.A. (2009).** Assessment of bioaccumulation of heavy metals by different plant species grown on fly ash dump. *J. Ecotoxicol. Environ. Safety.*, **72**: 1122-1128.

**Javid, S., Akhtar, A., Inam, A., Khan, N.A., Sheikh, F.A. and Shah, S.H. (2003).** Impact of sewage wastewater on physiomorphology and grain quality of wheat CV.HD-2329. *J. Poll. Res.*, **22**: 381-384.

**Javid, S., Akhtar, A., Khan, N.A. and Inam, A. (2003).** Effect of Rhizobium and NPK on growth, physiomorphological traits and yield of wastewater grown blackgram. *Indian J. Pulses Res.*, **16**: 25-30.

**Javid, S., Inam, A., Khan, N.A. and Singh, S. (2006).** Photosynthesis, growth and yield response of black gram (*Vigna munga*) to sewage and thermal power plant wastewater. *Physiol. Mol. Biol. Plant.*, **12:** 325-327.

**Kabata-Pendias, A. and Pendias, H. (1984).** *Trace Elements in Soils and Plants.* CRC Press, Inc, Florida, USA.

**Kabata-Pendias, A. and Pendias, H. (1992).** *Trace Elements in Soils and Plants.* 2$^{nd}$ Ed. CRC Press, Boca Raton.

**Kalavrouziotis, I.K., Robolas, P., Koukoulakis, P.H. and Papadopoulos, A.H., (2008).** Effects of municipal reclaimed wastewater on the macro- and micro-elements status of soil and of Brassica oleracea var. Italica, and *B. oleracea* var. Gemmifera. *J. Agric. Water Manage.*, **95**: 419-426.

**Kannabiran, B. and Pragasam, A. (1993).** Effect of distillery effluent on seed germination, seedling growth and pigment content of *Vigna mungo* (L.) Hepper cv. T-9. *Geobios,* **20**: 108-112.

**Kanwar, J.S. and Sandha, M.S. (2000).** Wastewater pollution injury to vegetable crops-a review. *Agric. Rev.*, **21**: 133-136.

**Khan, N.A., Gupta, L., Javid, S., Singh, S., Khan, M., Inam, A. and Samiullah, (2003).** Effects of sewage waste water on morphophysiology and yield of *Spinacia* and *Trigonella.* Indian. *J. Plant Physiol.*, **8:** 74-78.

**Khan, S., Aijun, L., Zhang, S., Hu, Q. and Zhu, Y. (2008).** Accumulation of polycyclic aromatic hydrocarbons and heavy metals in lettuce grown in the soils contaminated with long-term wastewater irrigation. *J. Hazard. Mater.*, **152:** 506-515.

**Khan, S., Cao, Q., Zheng, Y.M., Huang, Y.Z. and Zhu, Y.G. (2008).** Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. *J. Environ. Poll.*, **152**: 686-692.

**Kumar, P.P.G., Pandit, B.R. and Kumar, M.R. (1997).** Effect of dairy effluent on seed germination, seedling growth and pigment content of green gram (*Phaseolus aureus* L.) and black gram (*Phaseolus mungo* L.) Adv. *Plant Sci.*, **10**: 129-136.

**Lachover, D. and Arnon, I. (1966).** Observations on the relationship between heavy potassium deficiency and poor quality of several agricultural products of major crops. In: Potassium and the quality of agricultural products, P. 439-464. Proc. 8th Congr. Int. Potash Inst. Bern Hammet, L.K., Miller, C.H., Swallow, W.H. and Harden, C. (1984). Influence of N source, N rate and K rate on yield and mineral concentration of sweet potato. *J. Amer. Soc. Hort. Sci.*, **109**: 294-298.

**Lal, B. and De, R. (1972).** Fertilizer and moisture requirement of turnip. Indian *J. Agric. Sci.*, **42**: 156-160.

**Linzon, S.N., (1978).** Phytotoxicology excessive levels for contaminants in soil and vegetation, report of Ministry of the Environment. Ontario, Canada, 1978.

**Liu, W., Zhao, J., Ouyang, Z., Soderlund, L. and Liu, G. (2005).** Impacts of sewage irrigation on heavy metal distribution and contamination in Beijing, China. *J. Environ. Int.*, **31**: 805-812.

**Lokeshwari, H. and Chandrappa, G.T. (2006).** Impact of heavy metal contamination of Bellandur lake on soil and cultivated vegetation. Department of Chemistry Bangalore University. *Curr. Sci.*, **91**: 622-627.

**Lone, M.I., Saleem, S., Mahmood, T., Saifullah, K. and Hussain, G. (2003).** Heavy metal contents of vegetable irrigated by sewage/tubewell water. *Internat. J. Agric. Biol.*, **5**: 533-535.

**Longstreth, D. J. and Nobel, P. S. (1980).** Nutrient influences on leaf photosynthesis: Effects of nitrogen, phosphorus, and potassium for *Gossypium hirsutum L. Plant Physiol.* **65**: 541-543.

**Lonigaro, A., Rubino, P., Brandonisio, O., Spinelli, R., Pollice, A. and Laera, G. (2007).** Vegetable crop irrigation with tertiary filtered municipal wastewater. *Plant Biosys.*, **141**: 275-281.

**Lynch, J., Lauchli, A. and Epstein, E. (1991).** Vegetative growth of the common bean in response to phosphorus nutrition. *Crop Sci.*, **31**: 380-387.

**Mahida, U.N. (1981).** *Water Pollution and Disposal of Wastewater on Land.* McGraw-Hill Publishing Company Limited New Delhi. India.

**Markert, B. (1994).** Plants as biomonitors-potential advantages and problems. In: Adriano D.C, Chen Z.S, Yang S.S. (eds). *Biogeochemistry of Trace Elements.* Science and technology letters, Northwood, NY pp 601-613.

**Marschner, (2002).** *Mineral Nutrition of Higher Plants.* 2nd Ed., Academic Press, London.

**McIntosh, D. and Fitzsimmons, K. (2003).** Characterization of effluent from an inland, low-salinity shrimp farm: what contribution could this water make if used for irrigation. *J. Agric. Eng.*, **27**: 147-156.

**Mengel, K. and Kirkby, E.A. (1996).** *Principles of Plant Nutrition.* 4thEd. Panima Publishing Corporation, New Delhi.

**Mertz, W. (1969).** Chromium occurrence and function in biological systems, *Physiol. Rev.*, 49: 163.

**Mertz, W., Angino, E. E., Cannon, H. L., Hambidge, K. M. and Voors, A. W. (1974).** Chromium, in Geochemistry and the Environment. Vol. 1. Mertz, W., Ed. N.A.S., Washington, D.C., 29.

**Midrar-ul-Haq., Khattak, R.A., Puno, H.K., Saif, M.S., Memon, K.S. and Sial, N.B. (2005).** Toxicity of trace elements in different vegetables grown on potentially contaminated sites of the Korangi industrial area, Karachi Pakistan. *Asian J. Plant Sci.* **4**: 132-135.

**Midrar-ul-Haq., Khattak, R.A., Puno, H.K., Saif, M.S., Memon, K.S. and Sial, M.S. (2005).** Bioaccumulation of trace elements by different plant species grown on potentially contaminated soils of NWFP, Pakistan. *Asian J. Plant Sci.* **4**: 383-387.

**Miller, R.W., and Donahue, R.L. (1990).** *An Introduction to Soils and Plant Growth.* 6$^{th}$ Ed. Prentice Hall Englewood Cliffs, New Jersey.

**Mireles, A., Soils, C., Andrade, E., Lagunas-Solar, M., Pina, C. and Flocchini, R.G. (2004).** Heavy metal accumulation in plants and soil irrigated with wastewater from Mexico city. *J. Nucl. Instrum. Methods Phys. Res.*, 219-220, 187-190.

**Misra, R.N. and Behera, P.K. (1991).** The effect of paper industry effluent on growth, pigments, carbohydrates and proteins in rice seedlings. *Environ. Poll.*, **72**: 159-167.

**Monem, M.H.A.A.A. (1988).** Bacteriological examination of vegetables irrigated with wastewater in El simbellawein, Dakahlia, Egypt, *Annals Agric. Sci.*, **33**: 819-831.

**Moorby, J. and Besford, R. T. (1983).** Mineral nutrition and growth. In: *Encylopaedia of Plant Physiology.* **15** B: 481-572, A. Lauchli and R.L. Bieleski (Eds.) Springer Verlag, New York.

**Moreira, R., Chenlo, F., Vazquez, M.J. and Camean, P. (2005).** Sorption isotherms of turnip top leaves and stems in the temperature range from 298 to 328 K. *J. Food Eng.*, **71**: 193-199.

**Muchuweti, M., Birkett, J.W., Chinyanga, E., Zvauya, R., Scrimshaw, M.D. and Lester, J.N., (2006).** Heavy metal content of vegetables irrigated with mixtures of waste water and sewage sludge in Zimbabwe: Implications for human health. *J.Agric. Ecosyst. Environ.*, **112:** 41-48.

**Naheed, S., Ariz, N. and Beg, S. (1988).** Qualitative assessment of raw sewage effluents and accumulation of heavy metals in some vegetables. *Environ. Technol. Lett.*, **9**: 251-259.

**Nair, J., Levitan, J. and Oyama, N. (2008).** Zinc and copper uptake by silver beet grown in secondary treated effluent. *J. Biores. Tech.*, **99**: 2537-2543.

**Neilson, G.H., Stevenson, D.S., Fitzpatrick, J.J. and Brownlee, C.H. (1991).** Soil and sweet cherry responses to irrigation with wastewater. *Can. J. Soil Sci.*, **71**: 31-42.

**Nishijima, T., Sugii, H., Fukino, N. and Mochizuki, T. (2005).** Aerial tubers induced in turnip (*Brassica rapa* L. var. *rapa* (L.) Hartm.) by gibberellin treatment. *J. Sci. Hort.*, **105**: 423-433.

**Paliwal, K., Karunaichamy, K.S.T.K. and Ananthavalli, M. (1998).** Effect of sewage water irrigation on growth performance, biomass and nutrient accumulation in *Hardwickia binata* under nursery conditions. *Biores. Tech.*, **66**: 105-111.

**Panse, V.G. and Sukhtame, P.V. (1985).** *Statistical Methods for Agricultural Workers*, 4th Ed. Indian Council of Agricultural Research (ICAR), New Delhi.

**Pescod, M.B., (1992).** Wastewater treatment and use in agriculture. FAO irrigation and drainage. Paper 47, Food and agriculture organization of the United Nations, Rome, 125 pp.

**Rahaman, A.K.M.M., Alam, M.S., Mian, M.J.A. and Haque, M.E. (2007).** Effect of different fertilizers on concentration and uptake of cadmium by rice plant. *J. Agric. Res.* **45**: 129-134.

**Rajput, C.B.S. and Singh, V.B. (1982).** Effect of nitrogen, phosphorus, and potassium on growth and yield attributing characters of turnip. Haryana *J. Hort. Sci.*, **11**: 235-239.

**Rao, I.M. and Terry, N. (1989).** Leaf phosphate status, photosynthesis, and carbon partitioning in sugar beet. I. Changes in growth, gas exchange, and calvin engymes. *Plant Physiol.* **90**: 814-819.

**Rattan, R.K., Datta, S.P., Chhonkar, P.K., Suribabu, K. and Singh, A.K. (2005).** Long- term impact of irrigation with sewage effluents on heavy metal content in soils, crops and groundwater- a case study. *J. Agric. Ecosyst. Environ.*, **109**: 310-322.

**Reith, J.W.S. and Inkson, R.H.E. (1963).** Effect of fertilizers and farm yard manure on Swedes and turnips. *J. Agric. Sci. Camb.*, **60**: 145-157.

**Rodriguez-Sevilla, M.D., Villanueva-Suarez, M.J. and Redondo-Cuenca, A. (1999).** Effects of processing conditions on soluble sugars content of carrot, beetroot and turnip. *J. Food Chem.*, **66**: 81-85.

**Rothenberg, S.E., Du, X., Zhu, Y.G. and Jay, J.A. (2007).** The impact of sewage irrigation on the uptake of mercury in corn plants (*Zea mays*) from suburban Beijing. *J. Environ. Poll.*, **149**: 246-251.

**Sahai, R. and Srivastava, C. (1988a).** Effect of fertilizer factory waste on seed germination and seedling growth of two vegetable crop plants (*Brassica oleracea* L. var. Botrytis and *Brassica oleracea* L. var. Capitata). *J. Environ. Biol.*, **9**: 381-385.

**Sahai, R. and Srivastava, C. (1988a).** Effect of fertilizer factory waste on seed germination, seedling growth and pigment content of plants. *J. Indian Bot. Soc.*, **67**: 309-311.

**Salim, R., Isa, M., Al-Subu, M.M., Sayrafi, S.A. and Sayrafi, O. (1995).** Effect of irrigation with lead and cadmium on the growth and on the metal uptake of cauliflower, spinach and parsley. *J. Environ. Sci. Health.*, **30**: 831-849.

**Salisbury, F.B. and Ross, C.W. (1992).** *Plant Physiology*. 4$^{th}$Ed. Wadsworth Publ. Co., Belmont, California.

**Samiullah, Khan, N.A., Inam, A., Siddiqui, R.H. and Aziz, O. (1994).** Effect of treated Mathura oil refinery effluent on the performance of wheat. In: *Plant Productivity under Environmental Stress*. pp. 373-380. K. Singh, and S.S. Purohit, (Eds.) Agro-Botanical Publ. Bikaner, India.

**Schmit, J.N. (1981).** Le calcium dans le cellule generatrince en mitase Etude dans le tubo pollinique ch germination due chivia nokitis linall (Amaryllidacae) C. R. Adid. Sci. Ser. (III) 293, 755-760. In: *Mineral Nutrition of higher plants* (Ed.) Marschner, H. 2002, 2$^{nd}$ ed. Academic Press, London.

**Senesi, N. and Polemio, M. (1981).** Trace element addition to soil by application of NPK fertilizers, *Fert. Res.*, 2, 289.

**Shacklette, H.T. (1980).** Elements in fruits, and vegetable from area of commercial production in the Conterminous United States, U.S. Goel. Surv. Prof. Pap., 1178, 149.

**Shah, R.A., Javid, S. and Inam, A. (2005).** Effect of sewage irrigation and nitrogen rates on the growth and productivity of triticale. *Poll. Res.*, **24**: 267-274.

**Shahroz, B., (2009).** *Response of some Vegetable Crops to Wastewater.* Ph.D. Thesis, Aligarh Muslim University, Aligarh, India.

**Shalaby, M.H., Omran, M.S. and Raslan, M.I. (1996).** Effect of irrigation with different water wastes on the mineral composition of some medicinal plants. Fourth National Congress on Pollution Control of Agricultural Environment, Egypt. *J Soil Sci.*, **36**: 133-143.

**Sharma, G.C., Patel, A.J. and Mays, D.A. (1976).** Effect of SCU on yield, N uptake, and nitrate content in turnip greens, cabbage, and tomato. *J. Amer. Soc. Hort. Sci.*, **101**: 142-145.

**Sharma, R.K., Agarwal, M. and Marshall, F. (2007).** Heavy metal contamination of soil and vegetables in suburban areas of Varanasi, India. *J. Ecotoxicol. Environ. Safety.*, **66:** 258-266.

**Sharma, R.S., Agrawal, M. and Marsh'all, F.M., (2009).** Heavy metals in vegetables collected from production and market sites of a tropical urban area of India. *J. Food Chem. Toxicol.*, **47**:583-591.

**Sheoran, R.S., Sharma, H.C., Niwas R., Pannu, R.K. and Niwas, R. (1999).** Thermal efficiency of fenugreek (*Trigonella foenum-graecum L.*) genotypes under different sowing environment and phosphorus levels. *Indian J. Agric. Sci.*, **69:** 830-832.

**Shimada, N., Sato, Y., Mastsuo, K. and Kojima, N. (1977).** The efficiency of ammonium chloride as fertilizer on vegetable crops. Technical Bull. Faculty. Hort.No. **25:** 5-12 (cited from Hort. Abstr., **48**: 9807, 1978).

**Shivhare, R.L. and Pandey, C.S. (1995).** Effect of copper ore effluent on selected crops. *J. Ecotoxicol. Environ. Monit.*, **5**: 235-239.

**Shukla, N. and Moitra, J.K. (1995).** Effect of integrated steel plant effluent on growth parameters of selected pulses and cereals. *J. Environ. Biol.*, **16**: 71-73.

**Shukla, N. and Pandey, C.S. (1991).** Oxalic acid manufacturing plant wastewaters: effect on seed germination and seedling height of selected cereals. *J. Environ. Biol.*, **12**: 149-151.

**Siddiqui, R.H., Samiullah, Inam, A., Khan N. A. and Aziz, O. (1994).** Response of *Vigna radita* to treated Mathura oil refinery effluent. In: *Plant*

*Productivity under Environmental Stress.* Singh, K and Purohit, S.S. (Eds.), Agro-Botanical publishers Ind., Bikaner, pp. 367-372.

**Singh, A., Agrawal, S.B., Rai, J.P. and Singh, P. (2002).** Assessment of the pulp and paper mill effluent on growth, yield and nutrient quality of wheat (*Triticum aestivum* L.). *J. Environ. Biol.*, **23**: 283-288.

**Singh, D., Rana, D.S., Pandey, R.N. and Chauhan, I.S. (1995).** Yield response of fodder sorghum, maize and cowpea to varying NPK doses under waste water irrigation on Mollisols of western Uttar Pradesh. *Annals Agric. Res.*, **16**: 522-524.

**Singh, R.P. and Agrawal, M. (2007).** Effects of sewage sludge amendment on heavy metal accumulation and consequent responses of *Beta vulgaris* plants. *J. Chemosphere.* **67**: 2229-2240.

**Sirohi, P.S., (1980).** Try these turnip varieties. *Indian Hort.*, **25**: 4-5.

**Smirnov, P.M., Bazilevich, S.D. and Obukhovskaya, L.V. (1982).** Productivity of vegetable and fodder beet crops and their nitrate accumulation with application of nitrogenous fertilizers. IZV Timiryazev S-KH Akad., **0**: 53-62. (cited from Biol. Abstr., **76:** 3215, 1983).

**Smith, C.J., Hopmans, P. and Cook, F.J. (1996).** Accumulation of Cr, Pb, Cu, Ni, Zn and Cd in soil following irrigation with treated urban effluent in Australia. *J. Environ. Pollut.,* **94**: 317-323.

**Soils, C., Sandoval, J., Perez-Vega, H. and Mazari-Hiriart, M. (2006).** Irrigation water quality in southern Mexico city based on bacterial and heavy metal analyses. *J.Nucl. Instrum. Methods Phys. Res Sect. B.* **249**: 592-595.

**Stanhill, G. (1958).** Effect of soil moisture on the yield and quality of turnips. II, Response at different growth stages. *J. Hort. Sci.,* **33:** 264-274.

**Tabassum, D., Azad, S. and Inam, A. (2007).** Utility of city wastewater as a source of irrigation water for mustard. *J. Indus. Poll. Cont.*, **23**: 319-396.

**Tani, F.H. and Barrington, S. (2005).** Zinc and copper uptake by plants under two transpiration rates. Part II. Buckwheat (*Fagopyrum esculentum* L.). *J. Environ. Poll.*, **138**: 548-558.

**Thapar, A.R. (1960).** *Horticulture in Hill Region of North India.* p. 224. Directorate of Ministry of food and Agriculture, New Delhi.

**Thomas, H. and Stoddart, J.L. (1980).** Leaf senescence. Ann. Rev. *Plant Physiol.*, **31**: 83-111.

**Tisdele, S.L., Nelson, W.L., Beaton, J.D. and Havlin, J.L. (1995)**. *Soil fertility and Fertilizers.* 5th Ed. Prentice-Hall of India Pvt. Ltd. New Delhi India.

**Tiwari, D., Elcey, C.D. and Bhatia, I. (1993).** Response of two cultivars of Indian mustard (*Brassica juncea* L. Czern & Coss) to distillery effluent. *Geobios.*, **20**: 27-32.

**Truby, P. and Raba, A. (1990).** Heavy metal uptake by garden plants from Freiburg sewage farm wastewater. *Agribiol. Res.*, **43**: 139-146.

**Verloo, M., Eeckhout, M. (1990)**. Metal species transformations in soil: an analytical approach. *Int. J. Environ. Anal. Chem.*, **39**: 179-186.

**Verma, P., George, K.V., Singh, H.V. and Singh, R.N. (2007).** Modeling cadmium accumulation in radish, carrot, spinach and cabbage. *J. Appl. Math. Model.*, **31**: 1652-1661.

**Vieira, I.S., Vasconcelos, E.P. and Monteiro, A.A. (1998).** Nitrate accumulation, yield and leaf quality of turnip greens in response to nitrogen fertilisation. *J. Nutr. Cycl. Agroecosyst.*, **51**: 249-258.

**Vijayarengan, P. and Lakshmanachary, A.S. (1993).** Effect of textile mill effluent on growth and development of greengram seedlings. *Adv. Plant Sci.*, **6:** 359-365.

**Walkley, A.J. and Black, I.A. (1934).** Estimation of soil organic carbon by the carbonic acid titration method. *Soil Sci.*, **37:** 29-38.

**Wang, G., Su, M., Chen, Y., Lin, F., Luo, D. and Gao, S. (2006).** Transfer characterestics of cadmium and lead from soil to the edible parts of six vegetable species in southeastern China. *J. Environ. Poll.*, **144**: 127-135.

**Wilcox, L.V. (1955)**. Classification and use of irrigation waters. U.S. Deptt., Agric. Circ. 969, Washington, D.C, pp19. In: Mahida, U.N., (1981). *Water Pollution and Disposal of Wastewater on Land.* McGraw-Hill Publishing Company Limited New Delhi. India.

**Williams, D. E., Vlamis, J., Purkite, A. H. and Corey, J. E. (1980).** Trace element accumulation movement, and distribution in the soil profile from massive applications of sewage sludge. *Soil Sci.* **1292**:119-132.

**World Health Organization, (1989).** *Health guidelines for the use of wastewater in agriculture and aquaculture.* Technical Report Series 778. WHO, Geneva.

**Yadav, R. K., Goyal, B., Sharma, R.K., Dubey, S.K., Minhas, P.S., (2002).** Post-irrigation impact of domestic sewage effluent on composition of soils, crops and ground water- A case study. *J. Environ. Int.,* **28:** 481-486.

**Yamada,Y., Yabuki, S. and Ghoma, M. (1998).** Treatment with wastewater from seed disinfection in raising rice seedlings. *Japanese J. Crop Sci.*, **67**: 407-409.

**Yang, Q., Lan, C. and Shu, W. (2008).** Copper and Zinc in a paddy field and their potential ecological impacts affected by wastewater from a lead/zinc mine, P.R. China. *J. Environ. Monit. Assess.*, **147:** 65-73.

**Yang, Y., Zhang, F., Li, H. and Jiang, R. (2009).** Accumulation of cadmium in the edible parts of six vegetable species grown in Cd-contaminated soils. *J. Environ. Manage.,* **90**: 1117-1122.

**Yusuf, A.A, Arowolo, T.A. and Bamgbose, O. (2003).** Cadmium, copper and nickel levels in vegetables from industrial and residential areas of Lagos City, Nigeria. *J. Food Chem. Toxicol.,* **41**: 375-378.

**Zein, F.I., El-Yammani, M.S., El-Leithy, A.A. and Moustafa, A.T.A. (2002).** Effect of polluted irrigation water on some crops and their contents of heavy metals to sugarbeet. *Egyptian J. Soil Sci.*, **42**: 307-318.

**Zheng, N., Wang, Q. and Zheng, D. (2007).** Health risk of Hg, Pb, Cd, Zn, and Cu to the inhabitants around Huludao Zinc Plant in China via consumption of vegetables. *J. Sci. Total Environ.,* **383**: 81-89.

**Zheng-miao, X., Bi-ling, W., Ye-fang, S. and Jing, L.(2006).** Field demonstration of reduction of lead availability in soil and cabbage (*Brassica chinensis* L.) contaminated by mining tailings using phosphorus fertilizers. *J. Zhejiang Univ. Sci. B,* **7**: 43-50.

## APPENDIX-I

**Ammonium molybdate solution (2.5%)**

(a) 25g ammonium molybdate dissolved in 175 ml DDW (b) Add 280 ml concentrated $H_2SO_4$ to 400ml DDW and cool. Mix the two solutions (a) and (b) and final volume made upto 1 litre with DDW.

**Diphenyl amine indicator**

0.5g diphenyl amine dissolved in a mixture of 20ml DDW and 100ml concentrated $H_2SO_4$.

**Ferrous ammonium sulphate (0.5)**

196.1g hydrated ferrous ammonium sulphate dissolved in DDW. To this 20ml concentrated $H_2SO_4$ was added and final volume made upto 1000ml.

**Hydrochloric acid (1N)**

86.2ml hydrochloric acid mixed with DDW and final volume was made upto 1000ml.

**Potassium dichromate solution (1N)**

49.04g potassium dichromate dissolved in 1000ml DDW.

**Potassium Chloride (1N)**

74.56g potassium chloride dissolved in 1000ml DDW.

**Stannous chloride solution**

2.5g crystalline stannous chloride dissolved in 100 ml glycerol, heat and stir in water bath until dissolved.

**Sodium hydroxide solution (1N)**

40g NaOH dissolved in DDW and final volume made upto 1000ml.